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Overview on glass industry

Dr Can Apak

OVERVIEW OF ENERGY CONSERVATION IN GLASS INDUSTRY

Glass industry is one of the fast growing industries in India. The annual growth in 1995 is reported as 10%. The governmental policies relating to import controls, foreign exchange rates, allocation of industrial licences, import of investment items and reduction in excise duties has resulted in modernisation and expansion of the glass industry and in the last ten years, a large and modern glass industry has emerged.

On the other hand, efficiency and productivity of this industry can only be assessed when its figures are compared with those in the rest of the world. Mainly with the better of the range of figures.

The figures that shall be quoted below are averages that have been calculated in different surveys in Europe and by no means do they refer to a specific plant. When specific plants are considered, the figures wary within a wide range. For example: a detailed study on the energy consumption of 13 sites in the UK container industry showed that the total process energy consumption ranged from 1,360 to 3,350 kcal/kg. Although one must assume that these plants must have a basic difference in their design, it also shows that differences in design and approach can produce a 2.5 fold difference between the lower and upper end of the scale.

ANALYSIS OF ENERGY CONSUMPTION

Glass production involves the use of energy at different stages of the operation. But by far, the largest share of this use is in the melting furnaces. Although the distribution changes from one of production to another and depending on the size of production, average distributions would be as in Figures 1 and 2.

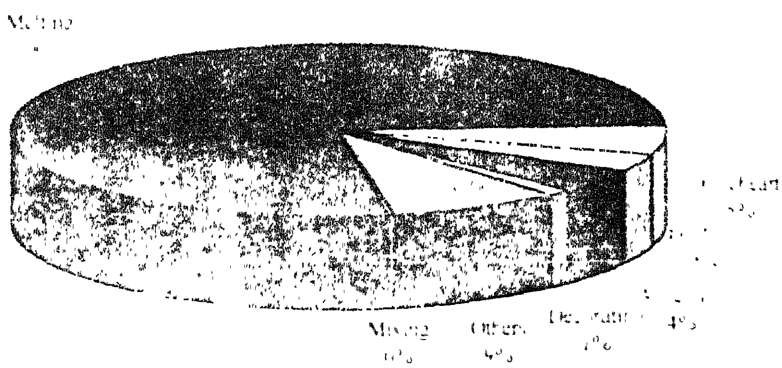


Figure 1. Distribution of consumed energy in flat glass production

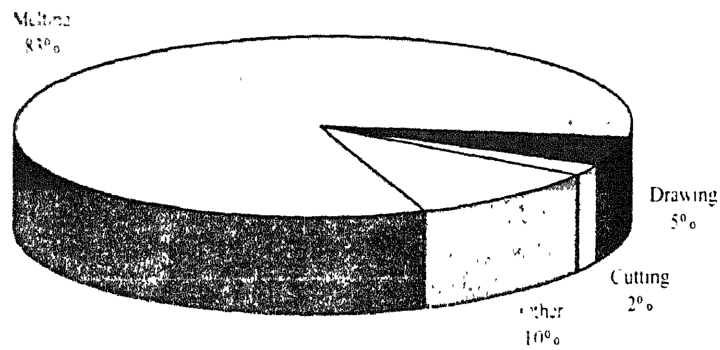


Figure 2. Distribution of consumed energy in container production

As can be seen from the diagrams above, energy use for melting exceeds 80% and in fact can be as high as 85% at larger furnaces. Therefore one must initially concentrate on the heat losses from the melting unit, the furnace.

HEAT BALANCE AROUND THE FURNACE:

The thermochemical heat required to convert one kg of dry glass batch at room temperature, to molten glass at the same temperature is calculated as 133 kcal. Theoretically this is the only energy needed to make glass. Of course, the glass has to be taken out of the furnace at around 1300 °C. It caries out its sensible heat which is lost on cooling. This accounts for another 380 kcal/kg. The exit temperature of the flue gasses from efficient regenerators can be as low as 300 °C. with these gasses, another 88 kcal is lost for each kg glass. These three items add up to 602 kcal kg whereas, the actual average consumption, calculated and published by the Energy Office for UK Glass industry are1487 kcal/kg.

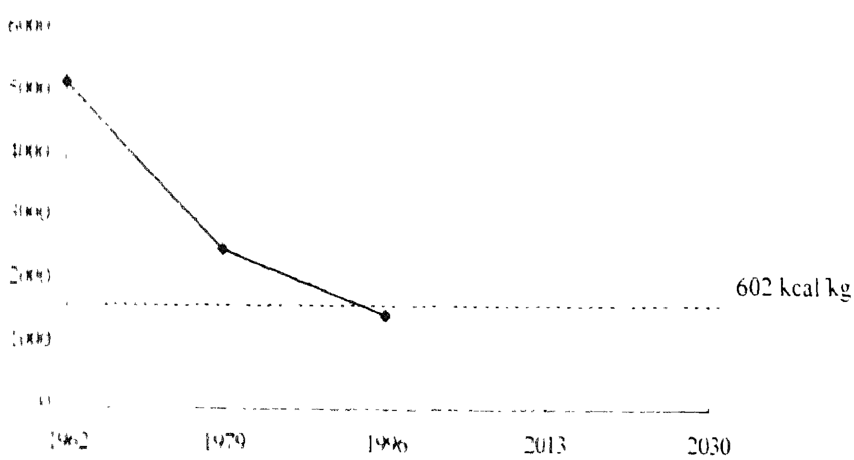


Figure 3. Change of specific fuel consumption of tank furnaces in time.

The modern tank furnace has been invented by Siemens in 19th century and the basic design has not changed much since then, but the detail of the design has changed to the standards of today. The original energy consumption of the furnace a century ago was 47,800 kcal/kg. A survey in UK in 1979 showed the same figure as 2520 kcal/kg and present day figures average 1487 kcal/kg. Figure 3 shows the change of these figures and compares them with the theoretical values. Although the consumption has decreased considerably in these years, the theoretical value of 602 kcal/kg indicates that there is still a long way to go.

The heat balance around the furnace is done by H. Barklage-Hilgefort and it is represented by a Sankey diagram which is given in figure 4.

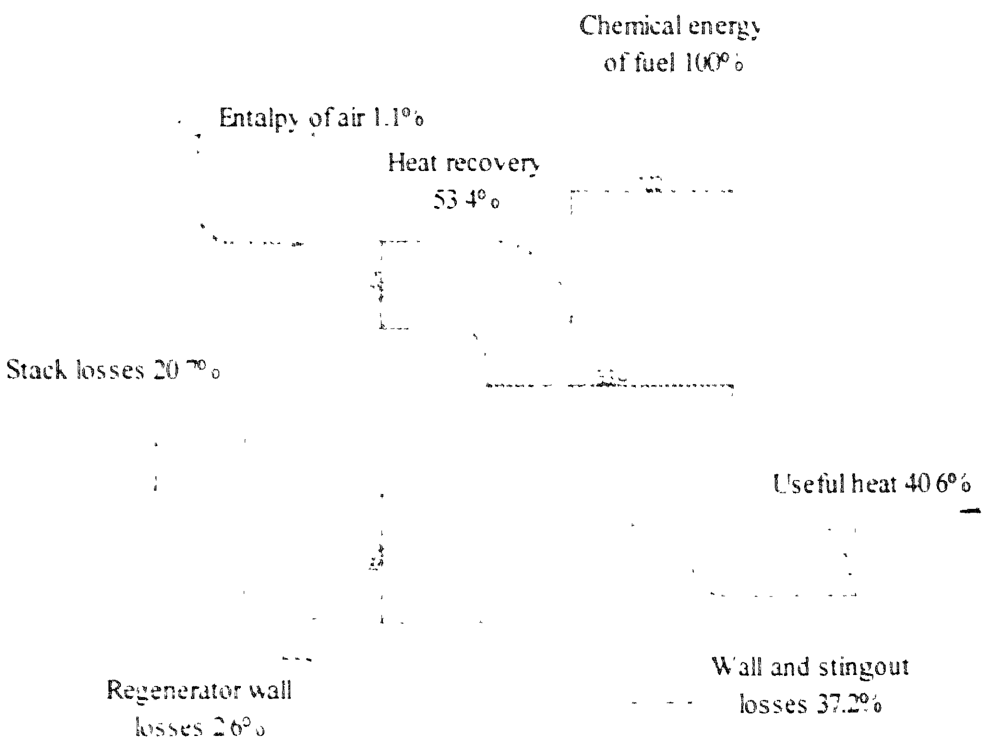


Figure 4. Sankey diagram of a Container Glass Furnace.

Wen the diagram is examined, it is seen that the thermal efficiency of a present day furnace is only 40.6% and this is so only with the help of a regenerator. Without a regenerator, the efficiency would fall to 20%.

Following this analysis, one can go step by step to the various actions that one can take to reduce energy consumption in a glass factory.

ACTIONS AROUND THE FURNACE:

Since the furnace is the main consumer of energy, it is natural to start with the furnace. The general principle of energy conservation around the furnace can be summarized as follows:

- Burn your fuel as efficiently as possible.
- Obtain the maximum possible flame temperature with minimum fuel.
- Loose as little energy as possible.

All the energy saving efforts concentrate on these main topics.

Regenerators:
The regenerator is the main and largest saver of furnace energy. A conventional regenerator recycles over 50% of the energy from the fuel and doubles the thermal efficiency of melting. The maximum theoretical efficiency of a regenerator is 80% but it is difficult to design a cost effective regenerator with more than 65-70% efficiency.

Insulation:
Insulation being the cheapest and most obvious one of the methods of energy saving, it is used most widely. But it must also be used with care otherwise it shall drastically reduce the furnace life. With the refractories of today, the upper structure of the furnaces can be extensively insulated but the glass contact refractories should not be insulated and after the initial few months, they must be cooled at least at the flux line.

Insulation shall not be limited to the furnace. Insulating the regenerators is equally important.

Furnace pressure:
It is necessary to keep a positive pressure inside the furnace to force the combustion products through the regenerators and up the stack. This pressure also pushes the gasses out through the openings of the furnace, which is the cause of the sting-out losses. These losses can be kept at a minimum by reducing the openings and keeping the furnace pressure as low as operation will allow.

Since the losses due to sting-out and through the walls through of the regenerators and the furnace constitute nearly 40% of the energy input and two third of all losses, halving these losses shall reduce the energy consumption of the furnace by 20%.

Electric boosting :
Electric boosting reduces heat losses from a furnace through three mechanisms.

Boosting increases the melting capacity of a furnace. Looking at it from the other angle, it decreases the volume of a furnace of a certain capacity. Decreased volume resulting in reduced surface area and consequently reduced heat loss through the surface.

Properly placed electrodes speed and regulate the back currents in the tank, decreasing the melting time and decreasing the heat losses during this time.

The volume of combustion products decrease with electric boosting and in case of all electric melting they are reduced to the carbon dioxide originating from carbonate decomposition and water vapor originating from crystal water and moisture.

Oxygen boosting:
Like electric boosting, Oxygen boosting also reduces heat losses from a furnace through three mechanisms.

Boosting increases the melting capacity of a furnace and it decreases the volume of a furnace of a certain capacity thus causing reduced heat loss through the surface.

Heat transfer to the melting batch is from an oxygen enriched fuel is higher, by the virtue of being hotter. Therefore melting is faster and heat loss during melting is less.

The volume of combustion products decrease with oxygen boosting and in case of all oxy-fuel melting, the 73-76% nitrogen which constitutes the composition of conventional fuel fired furnaces shall be absent.

Control and instrumentation:
In present day technology, control instrumentation, is an indispensable part of any furnace design. As a simple rule of thumb, each extra percent of excess air, increases the fuel consumption by 1%. Therefore it is important to keep the excess air at the required minimum. Monitored trials have shown that oxygen trim control on a 180 ton furnace has deceased the fuel consumption by 3.6%. Due to the present low cost of the electronic instruments, the pay-back period of such an investment is 1.4 years whereas addition of a second pass onto a regenerator pays itself back in 5 years.

The concept of control and instrumentation has significant implications when applied to the manufacturing operations as a whole. Currently the most efficient glass plants operate with a 90% efficiency and plants with product to melt ratios under 50% are not uncommon. Every kg of glass gone to cullet represents the loss of the energy put into that glass.

Cullet use:

Most plants recycle their in-house cullet. This restricts their cullet ratio to 10 to 20%. As mentioned above, since the melt going to cullet is a waste of energy, it should be kept at a minimum. On the other hand, 4% increase of cullet results in 1% reduction in fuel consumption of the furnace. Therefore if suitable foreign cullet is available, it must be used at high proportions.

Reduction of primary air:

Primary combustion air is used to spread and atomise the fuel. This speeds the combustion and reduces the need for excess air. On the other hand the primary air is fed to the burners as cold. In conventional burners where 10% of the air given as primary air, 3.5% of the energy input to the furnace is consumed to heat the primary air.

Burners employing no primary air not only save this 3.5% but also have better heat transfer efficiency due to the increased temperature of the flame. Therefore up to 4.5% energy saving can be expected from a burner without primary air.

Melt aids and glass composition:

Powerful fluxes like Lithium Oxide and Boron Oxide reduce the overall melting temperature and energy consumption of the furnace. With a well tailored batch composition can decrease the fuel consumption of the furnace by more than 10%.

ACTIONS OUTSIDE THE FURNACE

Over 20% of the energy consumed in a factory is consumed outside the furnace. Additionally, some of the actions taken outside the furnace can decrease the energy consumption of the furnace. The main items that can be included are as follows:

Lehrs:

A lehr is a piece of equipment used to cool the ware at a controlled rate. Therefore at the first sight, why does anybody need heat to cool an object. Starting from this principle, "no fuel" lehrs which utilise only the sensible heat of the ware are designed and some are operating. Best approach for annealing can be using a no fuel lehr but failing that energy input to the lehr must be kept at a minimum by proper insulation, proper circulation and introducing the ware into the lehr at above its annealing point.

Finding a suitable use for the heat rejected from the lehr further improves the heat economy of the system.

Cullet and Batch preheating:
The flue gasses emerging from the best regenerator leaves at 300 °C. On the average, they leave at 500-600 °C. This corresponds to over 20% of the energy input to the furnace. Such low quality heat can be used for various heating applications including the preheating of batch and cullet.

Commercial preheating system heat the batch and cullet to 300 °C and are reported to provide 15-20% energy saving.

Waste heat boilers:
As the size of the furnaces increases, the size of the additional regenerator volume to absorb the marginal heat also increases and for large furnaces, additional investment for this additional capacity becomes unfeasible. In such cases decreasing the regenerator size and diverting the hot flue gasses to a waste heat boiler becomes more feasible. The steam thus produced can be use to generate electricity and this electricity can be used to boost the furnace.

Use of such systems are not yet very common but there even are furnace projects with no regenerators with all of the waste heat being re-gained by waste heat boilers driving electric generators. This electric energy is returned to the furnace as electric boost.

Use of low quality heat:
In the glass plants, there are heat sources with even lower quality then the waste heat in the flue gasses. These are the radiative heat losses from the warm surfaces and the heat ejected from units like decorating tunnels in container and tableware plants, drawing chambers in sheet glass plants and the heat rejected from all lehrs.

The hot air from these units, if collected can be used in palletising the batch, heating the utility and process water and various heating and drying operations.

Batch palletising:
Batch palletising has a two fold effect.

To avoid batch segregation, glass batch is humidified. 2% of the fuel is used to warm and evaporate this moisture. Since the batch is dried during palletisation, this energy is saved without a risk of segregation.

During palletising, the sand grains are covered with soda particles. This increases the melting rate of the batch. With the increased homogeneity gained by palletisation, in effect, the melting process is accelerated and effectively as much as 5% energy gain is obtained through the use of palletised batch.

FACTORY SERVICES:

Areas other than the furnace consume a small part of the total energy consumption of the glass plant but what they consume are significant and it is definitely worthwhile to economise on this consumption.

Compressors:

Compressed air is the most expensive type of energy. Compressors convert only 10% of the energy they get into the energy of the compress air. The rest is converted to heat and lost. It is possible to convert this loss to useful energy by producing hot water or hot air but the best approach is to produce as little compressed air as possible and not to operate unnecessary compressor capacity.

Boilers and distribution lines:

A typical industrial boiler is 75-80% efficient. 15-20% of the heat is lost through the flue and another 1% is dissipated through the walls. Whenever possible, boilers should be operated by waste heat of the other units. When this is not possible, control equipment for oxygen trimming can provide 1-4% fuel efficiency.

Electric motors:

Electric energy is although expensive, is the most efficient type of energy. But because of its high cost it must be used with care. Capacity of the electrical appliances must be chosen according to the requirements. Over capacity heaters and motors waste electricity.

There are special low consumption motors available which consume 4-5% less electricity. They are slightly more expensive then the conventional motors. The difference in price is paid back after 5000 hours of operation.

All inductive loads disturb the phase angle between the current and potential of the electric input. The peak of current does not coincide with the peak of potential resulting in the reduction of the power factor.

Electricity supply companies charge extra for the reactive load on the network, which in fact is a loss of energy. This loss can be avoided by correcting this phase shift by a bank of capacitors or using low induction motors.

Other electric applications:

Lighting is responsible for only 1% of the electric energy used in a glass plant. Still it has a potential for energy preservation. Proper selection, installation and maintenance of the lighting system can help save significant quantities of energy.

CONCLUSION:

Preservation of energy in a glass plant is a team work. It must be undertaken by a group of active technical people, lead by an expert. Follow-up and control is as important as planning and implementation. I t must be planned executed by an office whose sole job is energy management and whose immediate superior is the top manager. This group must never be placed into or under the production management.

As a last comment, energy management can make the difference between the profit and loss of a plant.

Role of refractory design and specifications in energy conservation

S P Basu
Tata Refractory

ROLE OF REFRACTORIES DESIGN AND SPECIFICATIONS IN ENERGY CONSERVATION FOR GLASS INDUSTRY

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Role of Refractories Design and Specifications in Energy Conservation for Glass Industry

Introduction : Incredible changes have been found in the technology of glass making over the last sixty years or so. Among the number of changes taken place, major ones where the refractory design and specifications play important role are . -

- Furnaces have become larger
- Very long lasting life of refractories
- Efficient use of fuel
- Increased cost effectiveness

In order to cope up with the above mentioned apparent changes in operation practice, refractories type with regard to their quality, specification, shape, etc. had to be changed. The development of new to newer refractories has since been an ongoing system. From the following brief comparative data, the past and present picture can be made a little clear and specific.

Operation Practice	***50 years ago***	***At Present***
Furnace Life	12 to 18 months	8 to 10 years
Crown Temperature	1400 °C	1500 - 1600 °C
Melting Rate	16 - 20 ft^2 / ton	3 ft^2 / ton
Insulation Practice	Practically Nil	Heavily Insulated

Though all these changes in furnace performance have been brought about by better furnace designs and improvement in fuel technology, continuous improvement in quality of refractories and availability of selected refractories have played a major role all the time.

It is a fact that the glass industry globally is considered to be a large consumer of heat energy and operates at very high temperature. Hence the operational costs involved are not only very expensive but the system is also very difficult to handle and pose a number of risks towards the safety factor as well as towards the environment

The reduction in heat loss in the operation process therefore would be highly desirable to the extent possible and also beneficial for effective furnace operation. Before approaching the concept of application of insulation to the furnace structure it is important to have an understanding of the design aspects

of the furnace structure and the heat flow mechanism. This write-up deals with the basic principles of heat flow mechanism and the usage and effectiveness of different refractories in different locations of the furnace structure alongwith certain details of its properties, specifications, shapes, etc.

Heat Flow - Conception and Mechanism

Heat flow is a natural phenomenon where a temperature difference exists between two finite points till an equilibrium is achieved. Refractories in the furnace help in heat containment within the furnace by providing a thermal resistance to heat flow and thereby the equilibrium that nature seeks to impose. It is therefore to be understood that the refractories do not eliminate the heat flow but they do reduce it to a greater or lesser degree.

Heat flow mechanism is that the energy in the form of heat is transferred due to ......

- Atomic and molecular collisions in a conducting medium
- Wave motions produced by lattice vibrations
- Existence of particles in the molecular structure known as phonons.

Among the above mentioned three heat flow mechanisms, the wave motion and lattice vibrations are most relevant to the refractories. As we know, refractories are composed of either single oxide or mixed oxides which are usually crystalline in nature. Hence the thermal conductivity varies with the crystal nature and types of defects present in the lattice which again cause the interruption in the wave propagation. For example, a periclase crystal (MgO) will have a higher thermal conductivity than a magnesium compound such as forsterite ($2MgO.SiO_2$). This effect is common with alumina (Al_2O_3) and its compounds as well as several other refractory materials.

The heat flow in practice is largely depending upon the following major factors in case of refractories ....

* chemical composition of the material
* physical texture of the material
* temperature of the material
* other stresses, e.g. pressure, which the material is subjected to

The major types of heat transfer mechanisms are through conduction, convection and radiation either singly or a combination of either concurrently.

The simplest expression describing heat flow by conduction in the steady state is

$$Q = \frac{\text{Delta T}}{L/K}$$

where Q = quantity of heat flowing
Delta T = temperature drop from hot to cold face
L = thickness of the layer
K = thermal conductivity

The above expression is extended as follows for a multilayer arrangement of refractories lining in the furnace

$$Q = \frac{\text{Delta T}}{L_1/K_1} + \frac{\text{Delta T}}{L_2/K_2} + \frac{\text{Delta T}}{L_3K_3} + \ldots\ldots\ldots \frac{\text{Delta T}}{L_n/K_n}$$

where the values of L_1 ...... L_n and K_1 ...... K_n are the values of each layer respectively.

So, the interface temperature in such a multilayer system can be calculated from the expression

$$\text{Delta T} = L/K \times Q$$

It should be kept in mind that the thermal conductivity is neither linear nor necessarily rise with temperature in case of refractories.

The hot wire method of testing for finding out the "K" values of refractories in the laboratory is most popular compared to other methods because it is cheaper, quicker and accurate. It is also to be noted that some materials show significant anisotropy e.g., ceramic fibre blankets.

As temperature rises, heat transfer by radiation starts to assume importance in the overall heat flow system. By considering Boltzmann formula and Kirchoff's suggestion incorporating the emissivity factors, the calculation of radiating energy systems can be expressed as below

$$Q = 5.67\,E\ [T_{cf} - T_a]$$

where E = emissivity, T_{cf} = temperature of cold face, T_a = ambient temperature both in degrees absolute.

The most complex form of heat transfer is that arriving out of convection. Irrespective of its dealing with mathematically, experimentally or even through actual measurement in practice, it is important to consider that it not only involves the energy transfer between different states of matter but also involves the complexity of fluid dynamics.

Hence in this case the heat flow is to be quantified from the furnace atmosphere through a boundary layer and through the refractories and insulation layer through another boundary layer to the atmosphere. Besides, it is also important to take care of the fluid dynamics of the furnace atmosphere, the gas in the pores of the refractory media and outside atmosphere. So we find that the convective heat transfer is largely affected by the amount of porosity, pore size distribution as well as to whether the pores are open or closed in the refractories. That is how it is found that one of the most effective type of insulation material is ***microporous insulation***. Its low heat transfer rate is a result of not only the composition but also that it has a very low porosity where the pore diameters are very small and also closed and isotropic.

Convection at the surface of a refractory system is related to a both a velocity boundary layer and a thermal boundary layer. These are never coincidental but are interdependent. Newton's law expresses the convective heat transfer as

$$Q = h \times A \times \text{Delta } T$$

where Q = total heat loss, h = film coefficient, A = total area, and delta T = temperature difference.

In practice, however, it is important to consider the factors like shapes of the surface, smoothness, edge effects, composition of fluid and its velocity Besides, the important issue is to know whether the convection is natural or forced and whether it is laminar, turbulent or mixed.

For refractory systems there are generally two accepted formulae for natural convection The one which is most popular is directly related to the above mentioned Newton's formula where the film coefficient is defined empirically Considering the basis as vertical flat slab and incorporating the necessary corrections as relevant, the equation becomes

$$Q = \frac{1.25}{0.25\,(\text{Delta } T)}$$

Therefore, it is found that the total heat transfer is the sum of conduction, convection and radiation where the design of refractories with regard to its quality, type, specification, phase composition, etc. has a major role to play in the entire system. However, nowadays, with the input of correct data in the right order, the necessary calculations are done through the commercial software packages which saves time and energy by avoiding the complex calculations involved in the total heat flow system.

Role of Refractories design

For quite some time, there has been a lot of discussion in various conventions, seminars and colloquiums about the possibility of saving energy by controlling different factors related to the heat escape route from the glass making units From basic conception, we all know that the heat losses can be categorized as below :

⇒ sensible heat in glass

⇒ stack loss

⇒ structure loss

While the first two factors depend exclusively on the furnace design features (which is out of the scope of this paper), selection of refractories according to their properties, shapes, the refractories lining system and their installation technique play some role in improving the energy efficiency by reducing the heat loss from various parts of the furnace. Combining all these components, a concept of ***total refractories engineering system*** is felt to be one of the effective ways of achieving the goal.

For refractories related issues, our attention needs to be focused mainly on ....

- More effective preheating of the combustion air by optimized design of regenerator and checker system refractories
- Heat reflected from the wall (mirror effect)
- Heat absorbed by the wall and again emitted (conversion)
- Heat passes by conduction through the brickwork to the outside (loss)

The following two situations exist in the system : -

1. Radiation between refractory wall and gas space (Q_1) which can be represented by the following expression ....

$$Q_1 = A_R . C. E_R (E_G .T_G^4 - L_G.T_R^4)$$

where, A_R = area of refractory wall

C = Stephen Boltzmann constant

E_R = emission coefficient of refractories

E_G = emission coefficient of gas space

T_G = absolute temperature of gas

T_R = absolute temperature of refractory wall

L_G = absorption coefficient of gas

2 Similarly, the radiation between refractories wall and glass bath (Q_2) can be expressed as .

$$Q_2 = E_{RB} . A_B . C (T_R^4 - T_B^4)$$

with the resultant emission ratio (E_{RB})

$$(E_{RB}) = \frac{1}{1/E_B + A_B / A_R (1/E_R - 1)}$$

where A_B = area of glass bath

C = Stephen Boltzmann constant

T_B = temperature of glass bath

E_B = emission coefficient of glass bath

Hence it gives an impression that the radiation of superstructure wall on the bath can be improved by increasing the refractories wall surface area (A_R) and emission coefficient of refractories wall (E_R)

However, the reflected part of the radiation being of the same wave length of narrow range of radiation components in the gas mainly CO_2, it can always be absorbed by the exhaust without reaching the glass bath.

From the absorbed and emitted part of radiation covering the total wave length 80% reaches the glass bath for heating it leaving a small part which is again absorbed by the exhaust gas.

So we find that a corrugated type brick shape with cavity and larger surface area facing the increased gas volume will offer :

◊ Better utilization of the heat from the exhaust

◊ Due to cavity in the brick surface the radiation behaviour would be somewhat closer to "black body" which would eventually increase the emission coefficient of the refractories wall.

Hence it is important to consider the shape of refractories particularly for the inner contour of the superstructure which will also offer the following advantages in operation system by reducing the cost of energy.

(1) Faster glass melting rate

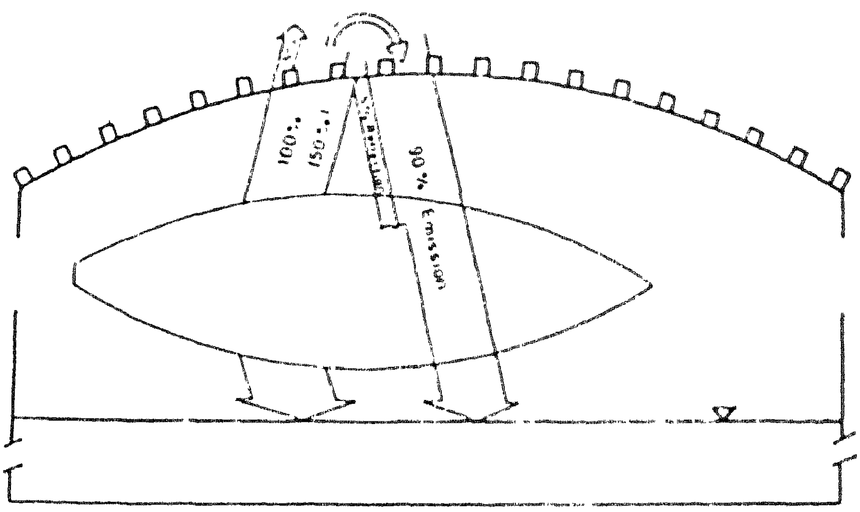
(2) Quality and homogeneity of the glass is improved

(3) Increase of bottom bath temperature

(4) Lower superstructure temperature and hence lower wear rate of refractories

(5) Increased top bath temperature with a formation of turbulence zone due to hollow space in refractories surface.

Shaped refractories wall for better emission effect



From a published data, the effectiveness of the special shaped refractories in superstructure is mentioned below as a typical case study.

Operation Details	***Furnace 1***	***Furnace 2***
Tank Type	Endfired	Endfired
Melting Surface	33 m^2	71 m^2
Specific Melting Rate - with special shaped bricks - with traditional bricks	 1.8 - 2.7 t/m^2 d 1.9 - 2.4 t/m^2 d	 2.5 - 3.1 t/m^2 d 2.5 - 2.9 t/m^2 d
Fuel	Gas	Gas
Crown Temperature (°C) with melting rate (t/m^2 d) - with special shaped bricks - with traditional bricks	 1.9 - 2.4 1520-1550 1560-1580 1560-1590 1610	 2.5 - 3.1 1530-1580 1560-1610 1570-1610 -
Specific Energy Consumption (kcal/kg) with melting rate (t/m^2 d) - with special shaped bricks - with traditional bricks	 1.9 2.7 1480 1326 1820 -	 2.5 3.1 1234 1020 1400 -

<u>Refractories type and specification of superstructure</u>

Variety of alumino-silicate, high alumina and silica refractories have been tried in different locations of the superstructure in glass melting furnace. The use of alumino-silicate and high alumina refractories in critical areas of superstructure has to be limited owing to their inherent properties. Another reason for their limitation is that when they come into contact with batch dust, they are inclined to grow (expansion) due to the formation of nepheline (Na_2O - Al_2O_3 - SiO_2 compound). Certain forehearth expendables, thermocouple sheaths, crucibles, etc. are however made of higher alumina content.

A special exeption of course applies for sintered and fused mullite based high alumina bricks which are successfully used in roofs and superstructure of fibre glass furnace and also in stack areas of unit melter furnaces. These have also shown success in the ports of cross fired furnaces. Fused mullite has a better thermal shock resistance due to larger crystal size and higher crystal density.

Typical properties of various alumino-silicate and high alumina bricks are shown in the enclosed sheet. The specification being the contractual values of different properties, these are always decided depending on the area of application under given operating conditions of the furnace.

Typical Properties of Alumino-Silicate and High Alumina Refractories

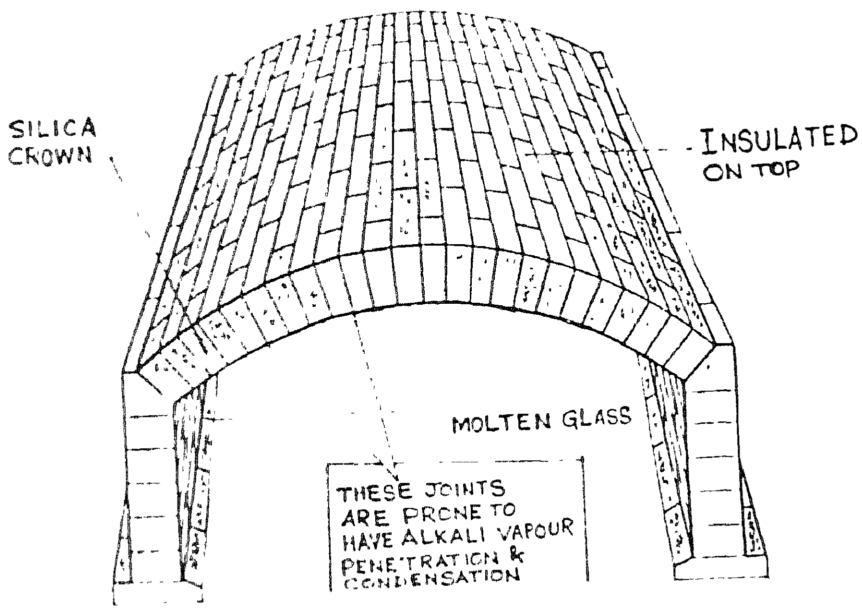
Properties	20-30% Al_2O_3	36-38% Al_2O_3	40-43% Al_2O_3	44-46% Al_2O_3	54-58% Al_2O_3	58-63% Al_2O_3	90% Al_2O_3	Fused Mullite	Sintered Mullite
Chemical (wt.%)									
Al_2O_3	24.03	37.08	40.5	46.0	56.20	62.0	91.32	75.5	72.8
SiO_2	68.88	57.32	54.0	50.0	38.42	36.0	4.50	24.0	25.0
TiO_2	1.24	1.15	1.5	2.0	1.85	1.03	2.05	0.1	0.2
Fe_2O_3	2.67	2.66	2.3	1.2	2.34	0.90	1.80	0.2	0.5
CaO	0.50	0 58	0.3	0.1	0.42	0.10	0.20	0.1	0.1
MgO	0.42	0.24	0.60	0.3	0.28	0.20	0.10	0.1	0.3
Na_2O	1.11	0.35	0.10	-	0.12	0.10	-	0.2	0.2
K_2O	0 90	0.52	1.0	0 1	-	0.40	-	0 1	0.1
Apparent Porosity (%)	18	20	18	10	13-17	16	22-25	16	13.5
B.D. (kg/m^3)	2.12	2 00	2.14	2.45	2.49	2.5	2.95	2.60	2 65
Thermal Shock Resistance (cycles at 1200 °C)	15	30+	30+	-	20+	30+	30+	30+	30+
RTE (at 1200 °C) %	0.7	0 5	0.5	0.6	0.6	0.6	0.8	0.5	0.5

Refractories for Crown

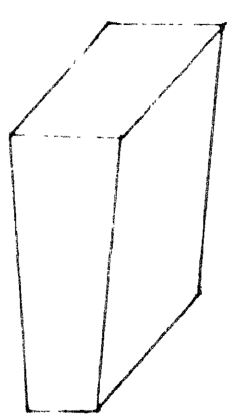
One of the most important areas related to energy savings is the crown in a glass making furnace In todays operation of modern glass tank furnace, most of the furnace crowns are heavily insulated and hence one has to very careful in selecting the refractories for crown.

As a general and universal practice, high grade superduty silica bricks are used in the crown. Due to higher bath temperature (1600 ° C or above), the superduty silica bricks are to be chemically pure with ***very very low flux content***. Hence a precise control on its chemical composition is extremely important. Secondly, due to the critical expansion behaviour of the polymorphic mineral phases and their allotropes present in the silica bricks (tridymite, crystabalite and quartz), a careful control ensuring the volume stability is also very important. Besides, to prevent the damage of crown due to hollow corrosion (popularly known as "rat holes"), perfect surface finish of the crown arch bricks is to be ensured. The phenomenon of "rat holes" occur when alkali vapour leaves through air gaps in brick joints towards outside direction, it condenses at lower temperature thus corroding the silica bricks.

This can be easily prevented by using precision silica bricks with respect to their surface finish and warpage. Finally during crown construction, thinnestmost possible tight joints without any air gaps are to be ensured.



TYPICAL WEDGE BRICK FOR CROWN



For manufacture of such high grade refractories, first of all, the refractory manufacturers have to start with a very pure raw material (quartzite). If the chemical composition of the raw material used is not within the specified norms, obviously the bricks made out of the same raw material will in no way be suitable for the purpose.

A typical analysis of such high grade quartzite suitable for manufacture of superduty silica bricks is shown in the next page.

Typical Analysis of Quartzite Raw Material

	Source A	*Source B*
Chemical (wt %)		
SiO_2	99.26	99.16
Al_2O_3	0.18	0.15
Fe_2O_3	0.26	0.17
K_2O	0.08	0.08
Na_2O	0.04	0.01
Flux Factor	0.42	0.33
PCE	SK 34	SK 34
Physical		
Crystal Size	30-40 microns	30-50 microns
Raw Material		
AP (%)	0.10-0.45	0.17-0.61
BD (gm/cc)	2.64-2.65	2.64-2.65
App. Spec.Gravity	2.65-2.66	2.65-2.66
Fired		
AP (%)	5.7-8.8	10.9-12.5
BD (gm/cc)	2.13-2.19	2.02-2.07
ASG	2.32-2.33	2.31-2.33
Residual Quartz	1-2	1-3.5

What to look for in Silica Refractories suitable for Crown ?

- The residual quartz content of the brick must be lower as high quartz content gives rise to unpredictable expansion characteristics. When the furnace is heated after construction it is to be kept in mind that by the time it reaches the operating temperature, the expansion should be least. Hence the control on quartz content in the brick is very important.

- The quartz content is related to the specific gravity of the brick. Usually a range of 2.32 to 2.34 (better if it is 2.32) ensures lesser quartz content in the brick. A direct petrographical examination or X-ray diffraction also can be done to find out the residual quartz content. A lower PLC (permanent linear

change) value also ensures the volume stability of the brick as well as indicates the optimum presence of Residual Quartz.

- Flux factor [Al_2O_3 + 2(Na_2O + K_2O)] in the brick should be lower to ensure higher softening point of the brick. Usually the value is controlled in the range lower than 0.5 to 0.8%.

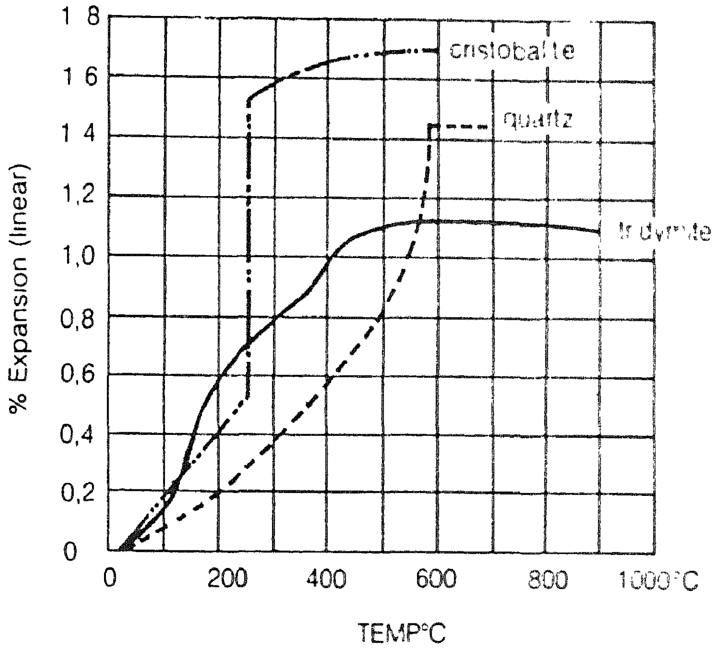
- Iron spots in the bricks if any should be evenly dispersed. Iron is an impurity in silica refractories which lowers down its refractoriness.

- The edges and corners should be sharp and free from surface warpage to ensure that proper pressing and firing operation have been followed.

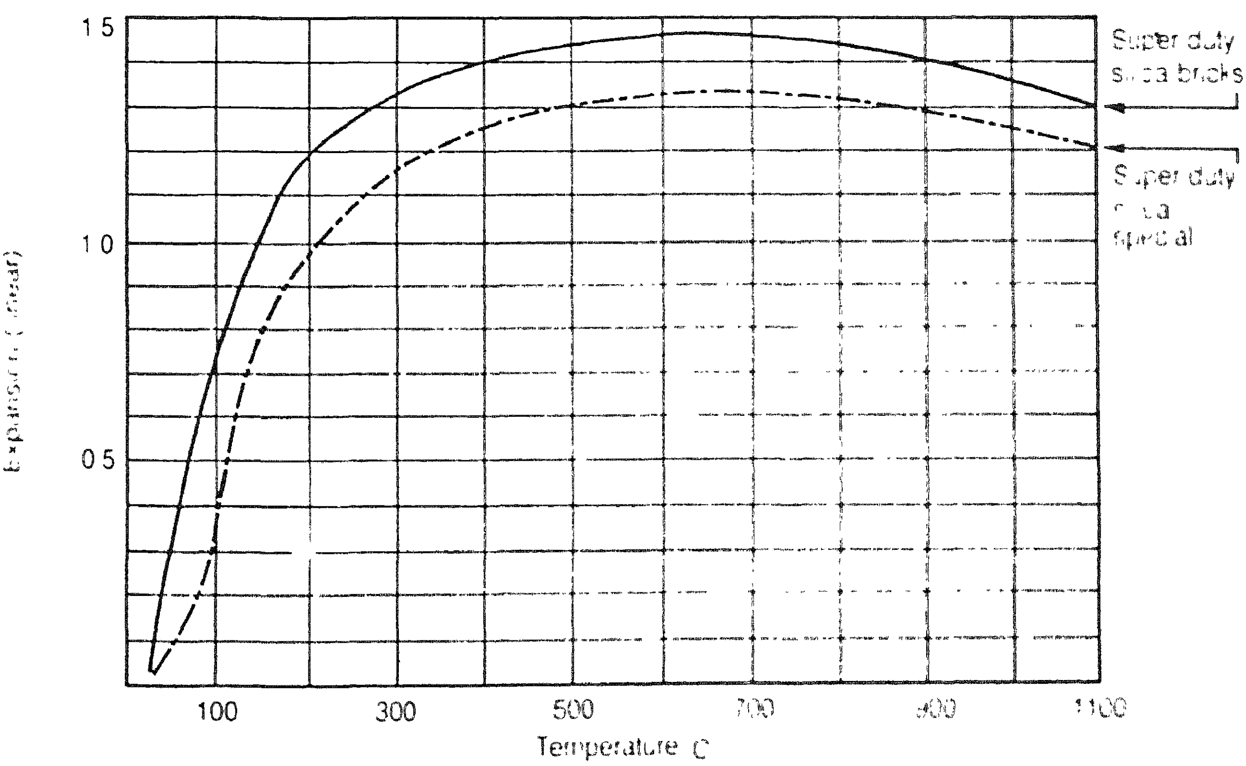
Dimensional tolerance is of extreme importance (poor fitting of bricks in crown can lead to open joints resulting in alkali penetration, condensation and eventually rapid wear).

Typical properties of indigenously available silica bricks suitable for insulated crown against the international standard is shown below.

Properties	***Indigenous Brick***	***International Standard***
Chemical (wt %)		
SiO_2	96.25	96.0
Al_2O_3	0.21	0.30
TiO_2	0.01	0.03
Fe_2O_3	0.27	0 23
CaO	2.65	2.60
Na_2O	0.07	0.04
K_2O	0.04	0.06
Flux Factor	0.43	0.50
Physical		
BD (gm/cc)	1 85-1.90	1.86
AP (%)	19-21	19 5
App Spec Gravity	2.32	-
CCS (kg/cm^2)	400-500	400
RUL (t_a °C)	1695	1685
RTE (at 1000 ° C)	1.20	1.40
Thermal Conductivity at 400 ° C at 700 ° C at 1000 ° C	 1 25 1.46 1.80	 1.30 1.50 1.80
Residual Quartz (%)	0.45	0.40



Thermal expansion of the various silica modifications



Thermal Expansion under load 2 kg cm²

Treatment of Silica Refractories in Service for Desired Performance in Glass Tank Crown

It is advisable to construct all silica structures with minimum possible joints, ideally less than 1 mm using a high purity silica mortar. Mortar with higher alumina content and thick joints leads to rapid wear and "rat hole."

At higher temperature, silica will react with alumina silicates and AZS readily. It is therefore important to use a buffer of an inert material during installation between two types of material. Zircon refractories are recommended for this purpose.

After construction, when all expansion of refractories has ceased, the outside is to be sealed to prevent the alkali penetration through the bricks.

Heavy insulation of silica minimizes the risk of alkali condensation. However it is imperative that the structure, if insulated, is well sealed otherwise the problem is transferred to the insulation.

During heat up of new construction with silica refractories, the heating rate should be very slow upto 700 ° C so that the mineralogical phase inversions that do occur can be adequately controlled.

Insulation

It is increasingly becoming a normal practice to have effective insulation in the glass making industry as one of the major measures for energy conservation. At present the energy cost is quite high and significant in overall cost of the end product. This is however open to variation with the age and size of the furnace and type of fuel used.

Effective crown insulation is very important for heavily loaded glass furnaces with constant pull with a melting temperature near 1600 ° C. Many a time, confusion was encountered with the belief that more efficient the insulation higher is the rate of corrosion and formation of rat holes in the crown. Through practice, it is however established that efficient insulation of silica crown working at higher temperature reduces the risk of condensation of alkaline vapours and eventual corrosion provided the loose brick joints are avoided or minimized

However, by using various insulating methods with different material some shortcomings were identified with the insulating materials. They are :-

(a) Some material show rapid rise of thermal conductivity at higher temperature

(b) Higher specific weight of insulating material limits the insulation thickness.

(c) Cracking of top coating material after a short period of operation.

(d) Deshaping and air infiltration through the insulating material.

To have effective insulation, the construction in several layers is normally recommended. In such case, a combination of four to five layers with different material having different thermal conductivity values is often used. A strong and durable cover coat with thermal sensitive properties is also to be used on the top.

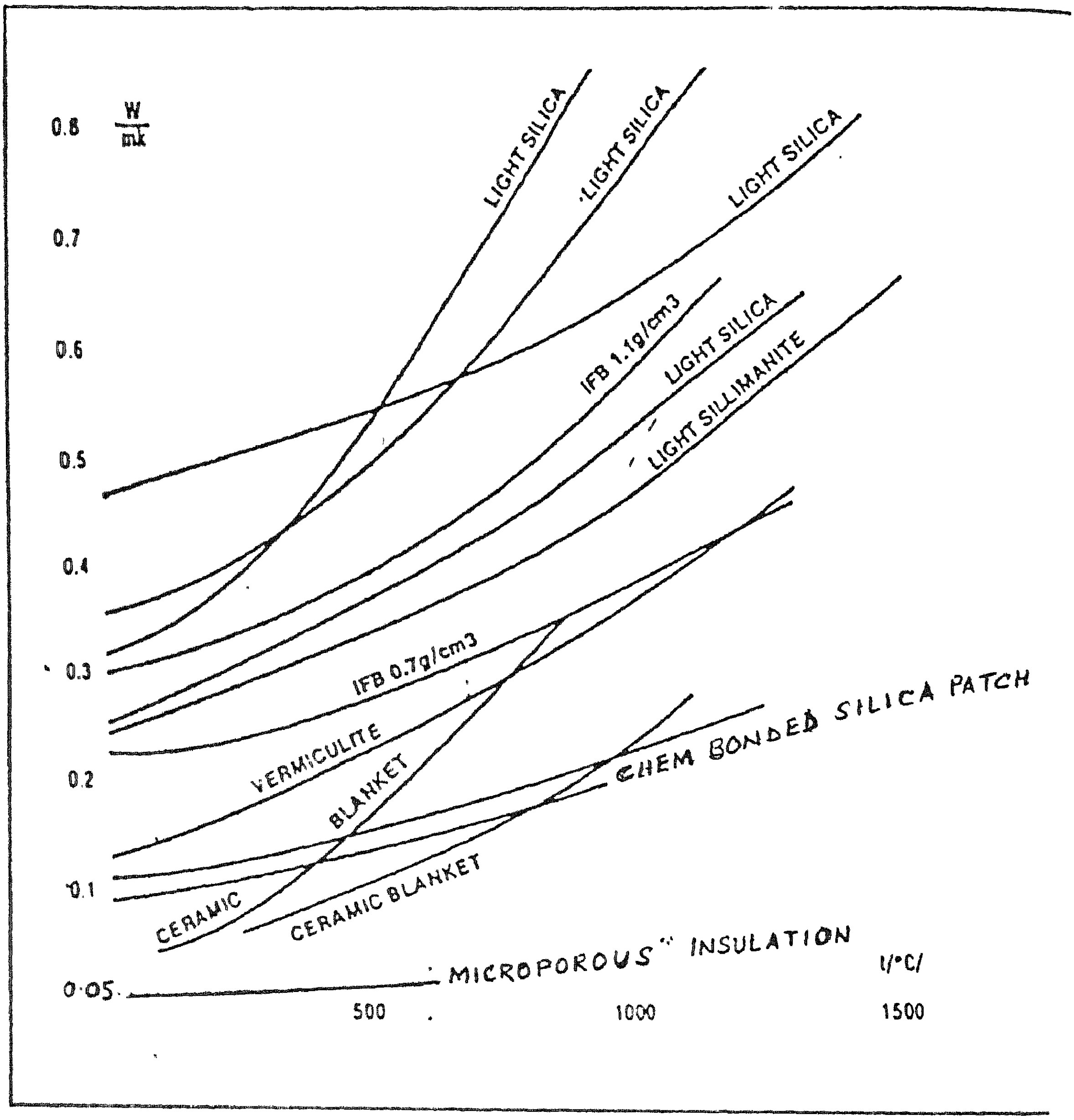
Microporous insulation which is made with ultrafine powder of amorphous silica is found to be an effective material for insulation as it contains extremely low pore size. Like ceramic fibre, it has got certain limitation towards chemical attack and abrasion and also to temperature range. The distinct advantage with this material is that it offers the lowest thermal conductivity among all other available insulating materials. The thermal conductivity values of various insulating materials are shown below.

Important aspects in introduction of insulating materials

Since the insulation material will have a direct effect the refractories adjacent to it, it is extremely important to consider various aspects associated with the system. The following criteria should therefore be examined and borne in mind

- chemical compatibility with the hot face refractories
- interface temperature and service temperature of hot face and intermediate materials
- internal wear
- efficiency requirement for the furnace
- structural losses
- desired campaign life
- requirement of preheated air for combustion and thermal efficiency
- steelwork design
- type of glass melted

Fig. Thermal conductivity of insulating materials



A schematic representation showing the recommended insulation material in various sections of the glass making furnace is shown below.

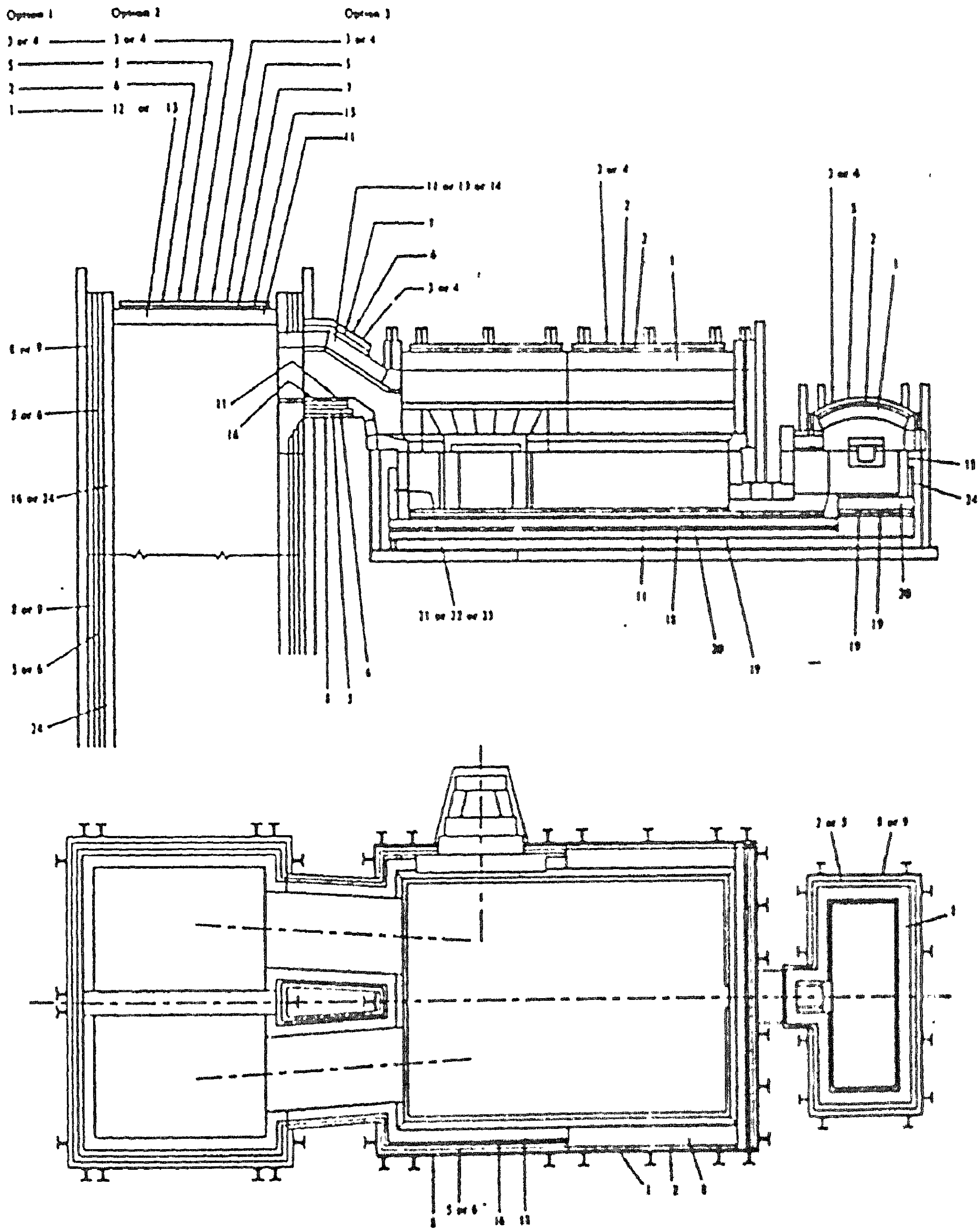


Figure 2. *Furnace insulation*

1 High duty silica
2 Porous silica
3 Fibre sinsulation
4 Wet blanket
5 125 (23) grade insulation
6 145 (26) grade insulation
7 155 (28) grade insulation
8 Diatomite brick
9 115 (20) grade insulation
10 Ceramic fibre board
11 Fused cast AZS
12 High alumina
13 Basic refractory
14 Mullite
15 Sealing cement
16 42% aldmina firebrick
17 50% alumina firebrick
18 AZS concrete
19 High grade insulation
20 Vacuum cast sillimanite
21 Zircon—firebrick
22 Firebrick—insulation
23 High alumina castable—insulati
24 37% alumina firebrick

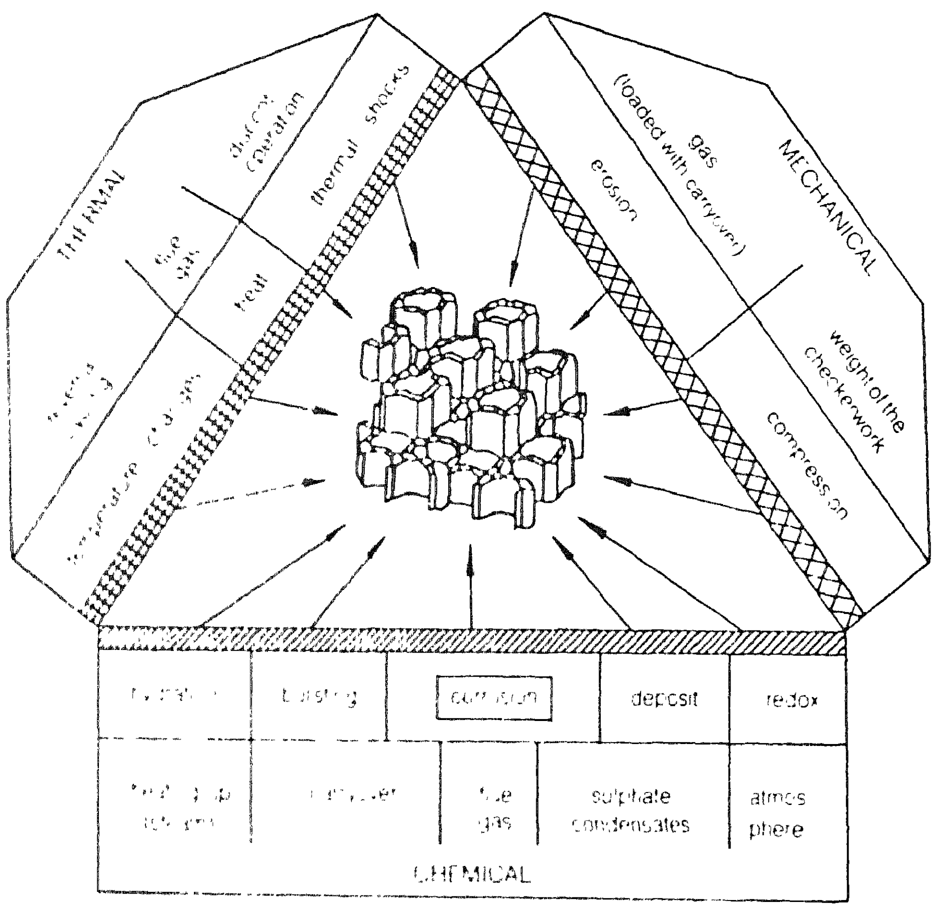
Regenerator Refractories

With the increased emphasis on the economical use of heat to save energy as already discussed in the preceding pages, we shall now shift our attention to regenerator chambers to find out the improvement as has already taken place as well as further possibilities to reduce the heat loss with special reference to the role of refractories used in it.

Behaviour of refractories under various stresses

The ultimate function of regenerator checkers refractories is judged on its merit of recovering heat from flue gas and feed it back to glass melting process. This mechanism has to be performed with minimum possible heat loss for the period over the years till the completion of furnace campaign life. During the functioning of refractories for such a long time, various influencing factors act on refractories for consequent changes in refractories with respect to deterioration in thermal effectiveness, inherent properties of refractories and losses arising out of wear. The conditions experienced by checker refractories due to such influencing factors are hereby being understood as stresses. There could be a number of sources where such influencing factors originate from. For explaining in a better way let us categorize the stresses as ***mechanical stress, chemical stress and thermal stress*** depending on their mechanism of acting on refractories and ultimate effect, attack or wear on refractories.

Stress and Strains on Refractory Checkerwork



Components carried over from glass batch and fuel (solid or gaseous) play an important role in determining the success of refractories w.r.t. its wear, corrosion and erosion. Besides, the cake formation by flue dust, sulphate condensation with deshaping of checkerwork refractories may cause a physical problem of "***plugging***."

The intensity of the stresses again is not uniform throughout the entire operation system but may vary with temperature, furnace atmosphere, type of fuel, etc In normal operation, type of refractories wear are directly related with the temperature due to impingement of refractories from various sources on it which is shown below.

Type of wear more at temperature >1200 °C	***Type of wear more at temperature <1200 °C***
• Carryover attack with CaO and SiO_2	• Alkali sulphate condensation
• Silicate bursting	• SO_3 attack
• Vanadium attack	• Borate bursting
• Boron attack	
• Redox reaction	

Selection of refractories for different portion of regenerator checkerwork

In order to have lower possible wear and deformation of refractories, a high corrosion resistant refractory against carryover attack and sulphates condensates with high microstructural stability is absolutely necessary Similarly, to cope up with the situation of thermal stresses arising out of sudden temperature change due to reversal cycling and discontinuous operation, a suitable brick with high microstructural flexibility **(thermally elastic)** is required.

The modern practice of better furnace insulation in order to reduce heat loss does not however affect the checkerwork to a great extent rather it causes thermal stress on roof by high temperature and flatter temperature gradient in the lining.

The energy supply crisis sometimes lead to a situation when varying qualities of fuel are used under compulsion. The consequence of such situation results in the fluctuations in the Na_2O/SO_3 ratio These variations have a direct effect on refractories due to the fact that in case of stoichiometrically balanced Na_2O/SO_3 ratio, the complete reaction takes place to form Na_2SO_4 salt which normally condenses between 800 and 1000 ° C. In case of a variation in the ratio, either there will be formation of Na_2O or SO_3 in excess i e., when $Na_2O/SO_3 > 1$ the regenerator checker and wall is subjected to Na_2O rich atmosphere and when

Na_2O/SO_3 < 1 they are subjected to SO_3 rich atmosphere. While Na_2SO_4 deposition on alumina based bricks can destroy them due to formation of nepheline ($NaAlSiO_4$), corrosion will take place due to a reaction of Na_2O with free SiO_2 containing brick and free CaO or MgO based refractories will readily be attacked in SO_3 rich atmosphere.

Hence we find a judicious selection of for use of proper refractories suitable for this situation is of great importance considering the fuel characteristics. However, spinel based bricks, hard fired direct bonded basic bricks with higher chromite content and magnesia bricks with zirconia addition has shown encouraging result for the application in ***sulphate condensation zone***

As a general practice, under normal operating conditions, the selection of refractories in various parts of regenerator checker is done as below .

Regenerator Checker	***Type of Refractories Recommended***
Top Course 1 (upper part)	96-98% MgO content direct bonded magnesia bricks
Top Course 2 (upper part)	90-95% MgO content conventional basic bricks
Middle Course (sulphate condensation zone)	High fired direct bonded mag chrome or magnesia alumina spinel or magnesia bricks with ZrO_2 addition
Lower Course (bottom)	Dense high alumina bricks (45-60% Al_2O_3)

A schematic representation showing the application of various refractories is shown in the next page

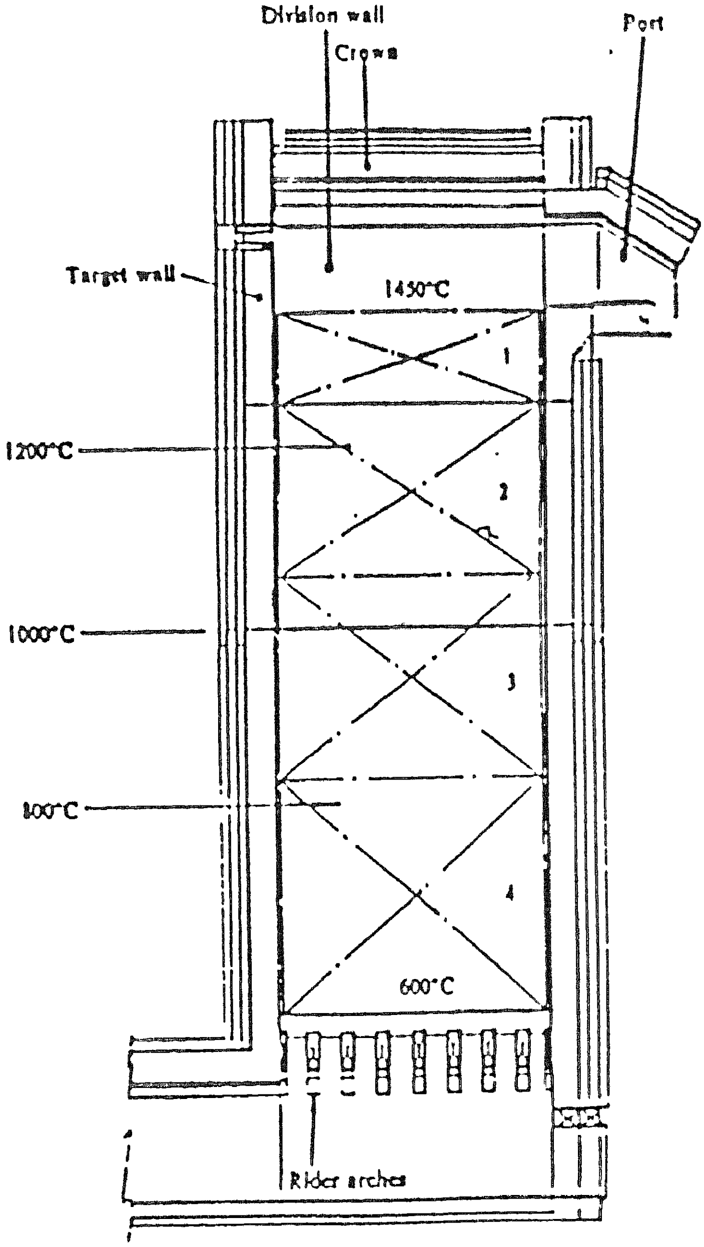


Figure *Typical chequer settings in a single pass regenerator chamber*

1 high fired direct bonded magnesia
2 conventionally fired magnesia
3 high fired direct bonded chrome–magnesia
4 dense aluminosilicate

A set of typical properties for various types of refractories used in regenerator checkerwork is appended below.

Properties	*Conventionally fired magnesia*	*High fired direct bonded magnesia*	*High fired direct bonded chrome magnesia*	*High fired magnesia chrome co-clinker*
Chemical analysis by XRF (wt %)				
MgO	93.0	96.3	51.0	59.5
Cr_2O_3	-	-	25.0	19.0
CaO	1.8	2.1	0.6	0.9
SiO_2	1.7	0.8	2.7	1.5
Al_2O_3	2.3	0.2	10.4	7.0
Fe_2O_3	1.1	0.3	9.5	11.5
Physical (BS 1902)				
B D (gm/cc)	2.90	2.98	3.15	3.15
A.P (%)	17.5	15.8	18.0	17.0
CCS (N/mm^2)	50.0	52.0	32.0	40.0
PLC at 1700 °C/2 h (%)	-0.2	Nil	+0.3	+0.3
MOR (N/mm^2)				
at 1100 °C	8.0	-	-	-
at 1200 °C	5 0	-	-	-
at 1300 °C	3 0	-	-	-
at 1400 °C	-	9.0	9.0	7.0
at 1500 °C	-	7 0	5.0	4.5
at 1600 °C	-	5.0	2.5	2.5
Creep at 1350 °C/50 h (%)	1.7	0.1	0 2	0.2
RUL (t_a °C)	1590+	1750+	1690+	1700+

Important properties for consideration while making a specification of regenerator refractories

Apart from the chemical purity, density and apparent porosity, some special thermal properties of regenerator checker bricks are of great importance to determine their volume stability during the campaign life

Thermal expansion

All fired basic refractories show a linear relationship with increasing temperatures upto 1400 °C with free reversible expansion properties depending on the type of refractories. The expansion of basic bricks being significantly higher than that of high alumina or fireclay bricks it is therefore necessary to design the expansion allowance for wall / roof to achieve optimum perofrmance of basic bricks.

Modulus of rupture

This property indicates the bond strength of the refractories at higher temperatures. The higher hot strength is associated with the development of an improved refractory matrix in the bricks. The matrix in case of magnesite bricks is $2CaO.SiO_2$ and hence at least a value of 2 for molar CaO/SiO_2 ratio in a magnesite brick composition is extremely important to ensure its hot strength at elevated temperature.

Even a magnesite brick has a desired CaO/SiO_2 ratio, presence of a little amount of boron in the composition of brick will cause a sharp decrease in hot strength. Therefore the control of boron content in magnesite bricks is extremely important for the consideration of its use in regenerator. A magnesite brick with high hot strength, high fired with high chemical purity and ultra low boron (B_2O_3) content is only suitable for use in upper part of regenerator wall and checker packings.

Compressive creep and refractoriness under load

Consideration of these two properties is extremely important when applying more thermally efficient back-up insulation of wall and roof structures to attain further improvements in heat utilisation. Increased insulation causes the working lining to operate at higher temperature and increased stress levels Hence the products with improved high temperature compressive creep and refractoriness under load characteristics have only to be chosen for the application in highly insulated regenerator to ensure a better performance over long campaign life under more arduous conditions

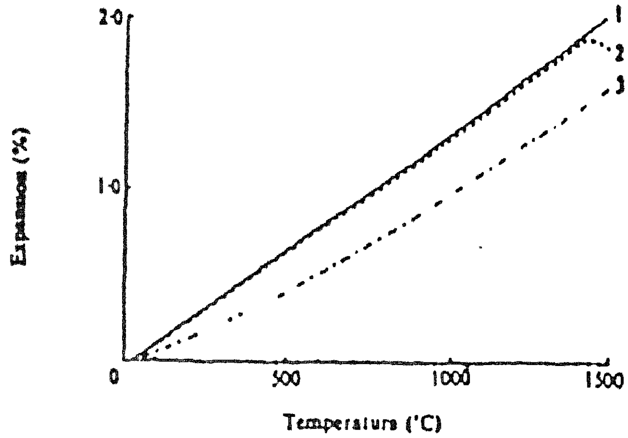


Figure · *Thermal expansion behaviour of fired basic products*
1 high fired direct bonded magnesia
2 conventionally fired magnesia
3 high fired direct bonded chrome–magnesia

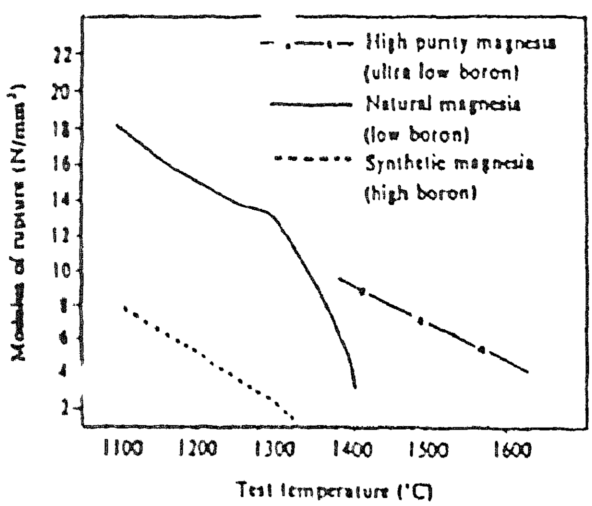


Figure *Effect of boron content on the modulus of rupture — temperature characteristics of fired magnesia*

Design and shape of various checker system (packing) in regenerator

The thermal efficiency of a glass tank regenerator is normally determined by the product of heating surface and convective heat transfer coefficient. The heating surfaces offered by various type of checkerwork are different from each other and also the heat transfer. Among the various available checker packing system, the following four vaieties are found to be used

- pigeon hole
- open basket weave
- chimney block
- cruciform

Although conventional chécker systems with 64 mm wall thickness (pigeon hole and open basket weave) are still prevailing, it is likely that the use of thin walled packing with chimney block and cruciform will soon be popular due to the various advantages as offered by the thin walled checkerwork. Let us now examine the major advantages and disadvantages offered by various checker packing system.

Structural stability

When we are talking about the structural stability, we should keep in mind that "***operational stability***" could be a different phenomenon which depends on the wear of refractories due to a number of operation variables and influencing factors involved in the system.

It is very easy to understand that structural stability will largely depend for a conventional checker packing system on the thickness of the refractories The thick walled refractories will always have higher packing density and larger support area. That is why open basket weave checkers (64 mm) offer better structural stability when compared to a pigeon hole system Now a thin walled body (40 mm) may also offer excellent structural stability provided its design and shape are properly engineered to offset the disadvantages of smaller support areas. Cruciform and chimney block packing both have shown encouraging result towards structural stability

Operational stability

As we have already discussed, the operational stability of checkerwork is largely dependent on the operational discipline followed during the entire campaign period of the furnace However, it has been observed that the most significant

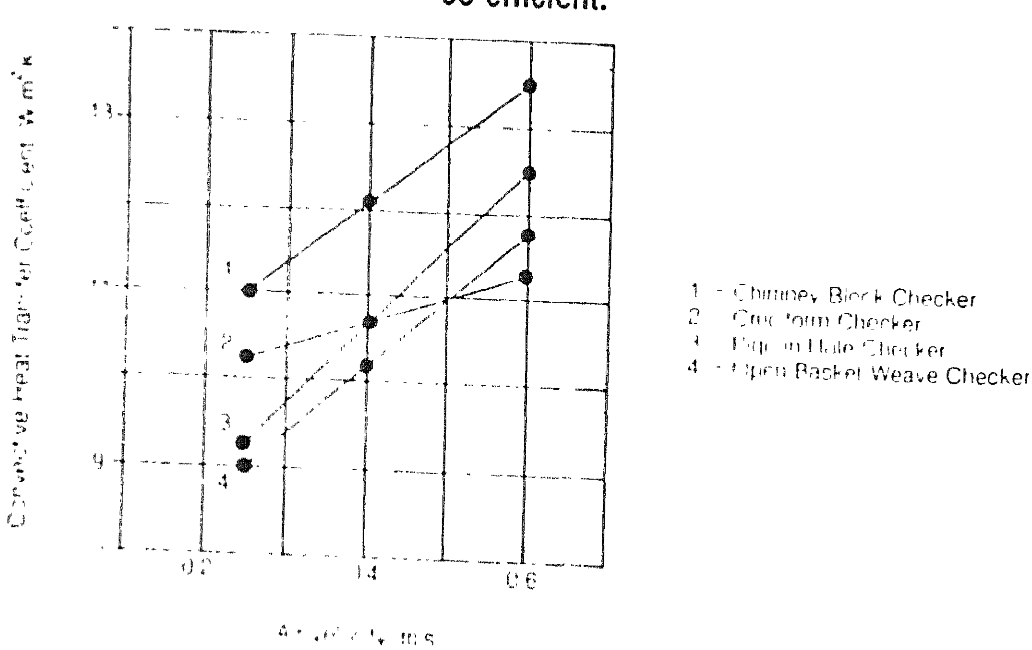
drawback of open basket weave packing is their tendency to ***brick rotation*** whereas the pigeon hole checkers are more susceptible to ***early corrosion*** due to their larger exposure of horizontal brick surface. Cruciform packing being made of ***very high grade material*** (fused cast) shows an improved operational stability. Chimney block also offers very good operational stability because of annular block shape and support of the elements provide to each other.

Thermal factors

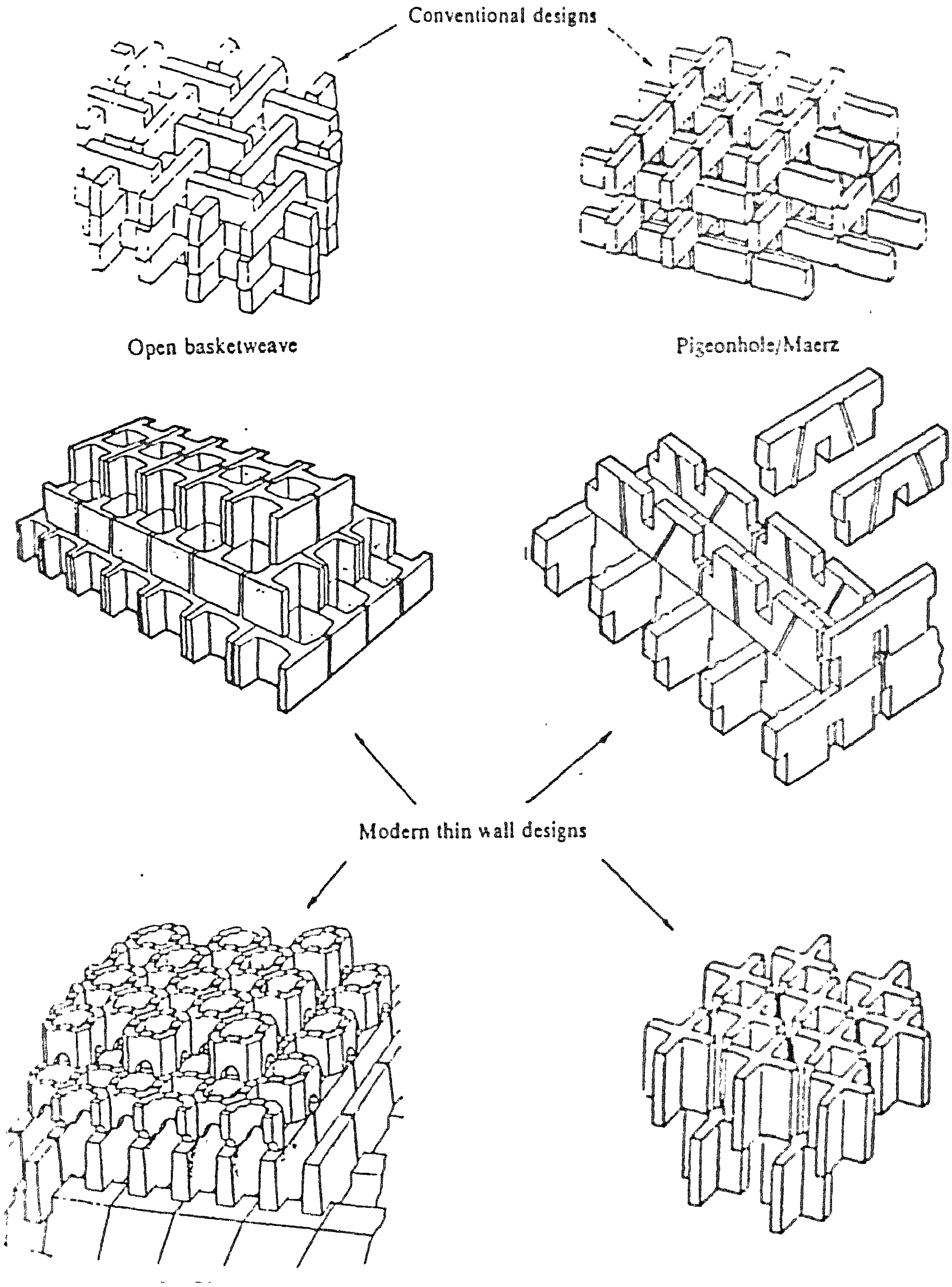
As has already been discussed, the efficiency of checkerwork is dependent on the heating surface and convective heat transfer coefficient (h_c) which arises out of the passage widths. It is obvious that for a given volume of regenerator chamber, the heating surface will be more if the walls of the checker bricks are thinner. Practical application has confirmed that the heating surface has increased by 50% when a 64 mm thick conventional basket weave packing has been replaced by 40 mm thick checkerwork. The published data show the following comparison between different checker systems.

Checker type	***Specific heat transfer area (m^2/m^3)***	***Specific brick mass (kg/m^3)***
Chimney block	17.07	1009
Cruciform	16.20	1059
Pigeon hole	13.24	936
Open basket weave	13.18	1144

The thermo technical efficiency of checkerwork is determined by the product of heating surface and the overall heat transfer co-efficient.



Various types of checkerwork in regenerator of glass tank furnace



With the above mentioned facts and results obtained by using various checker design, it is therefore important that depending on various operational parameters and size of the furnaces, the selection of proper shapes of regenerator checker brick should be done to have the desired thermal efficiency and consequent savings in energy.

Fusion Cast Refractories

The term fusion cast or fused cast refractories are similar to electrocast refractories. The name itself describes its mode of manufacture which essentially involves the melting of refractories batch in an electric furnace. The homogenous liquid material is then cast into moulds for desired shape. The special feature of fused cast refractories is that they are more as monolithic cast blocks instead of preformed structure with various grains and then fired to the desired shape.

Its remarkable success in glass industry was primarily due to its (a) very low porosity (b) interlocking crystal structure (c) very high refractoriness. The material is essentially composed of Al_2O_3, SiO_2 and ZrO_2 chemically. Later with the higher addition of ZrO_2 , the improvement in corrosion resistance properties was found. Subsequently the development of fused cast refractories, different grades of mag chrome, alumina chrome, super high zirconia, etc. were developed to meet the conditions of varying operational parameters in glass industry.

While its most important use is in glass contact areas in the glass making furnace with great success, trials are in progress to establish its suitability in other areas like superstructure and regenerators. This being a newer refractory for glass making units, lot of scope exists for its further improvement both in quality as well as in economics.

Conclusion

From the discussion we had so long on various aspects of role of refractories in energy saving for glass industry, it is still felt that the task is quite interesting though the achievement of goal to the extent of hundred percent would be highly difficult. However, it is believed that with close coordination with the glass manufacturers, the refractory makers would be achieving the goal to a great extent

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The write-up has been prepared by S.P.Basu, Marketing Division, Tata Refractories Limited, Calcutta for presenting in training programme on "energy efficiency and environment improvement in glass industry" at Tata Energy Research Institute, Pune.

Energy Saving Materials in Glass industry

Dr Can Apak

ENERGY SAVING MATERIALS
IN GLASS MANUFACTURE

REFRACTORIES:

The largest glass furnaces presently used are float glass furnaces.
A float glass tank uses over 7000 tons of refractories:

- 700 tons of silica,
- 1000 tons of chrome based
- 1000 tons of bonded regenerator pickings
- 1000 tons of fire bricks
- 3500 tons of fusion cast material.

These materials must have some common characteristics.

- Equal operation lives or operation life of one must be multiple of the other.
- High resistance to chemical attack from the media they are in contact with.
- Possibility of insulation.

Refractories in different parts of the furnace are analyzed from these angles.

Melting end, glass contact:

- Almost invariably fused casted zirconia-alumina-silicate.
- At parts with excessive corrosion, chromic oxide containing fused cast blocks.
- Very dense to resist liquid glass attack
- High thermal conductivity.

These refectories can be insulated very lightly near the base but the flux line must be cooled to slow dissolution at the flux line. Development of refractory types which can resist flux line glass attack at high temperatures that can be insulated heavily shall be welcome by the glass producers.

They produce bubbles in the melt but since the refining process is still going on here, it is acceptable.

Working end, glass contact:

- Density and corrosion resistance is required but evolution of bubbles must be avoided therefore fused casted zirconia-alumina-silicate is second choice
- Glass temperature here has decreased to around 1250 C. High alumina refractory which produces very little bubble can be used.
- High thermal conductivity.

Excessive insulation can still decrease the operation life but slightly more insulation can be used.

Side walls:

The quality requirements of the refractories of the side walls vary along the length of large furnaces.

- At the melting end where the conditions are more hostile, fused cast zirconia-alumina-silica or sintered or fused mullite bricks are preferred.
- Down in the working end, temperatures are lower and atmosphere is cleaner therefore refractories such as 72% Al_2O_3 mullite or 96% silica refractories can be used.
- Since these refractories do not carry load they can be insulated heavily.
- Insulation commonly used are porous silica or calc-silicate insulating brick.

Tank bottom:

- Tank bottoms are usually composed of two layers, one layer of zirconia base monolithic ram mix followed by AZS fused cast base blocks.
- In container furnaces which use external cullet, an extra layer of fused cast material is used to overcome the down-drill caused by the metal caps and to overcome the comparatively higher bottom temperatures.
- Tank bottoms are insulated liberally with insulating firebricks.
- In sheet glass furnaces, Fe_2O_3 content of the glass can be kept intentionally slightly high to keep the bottom temperatures lower and to decrease the heat loss from the bottom.

Crown:

- Conventionally, furnace crowns are made of silica bricks.
- The new "Honeycomb Brick" recently released by the company Didier is claimed to provide 5-8% energy saving by absorbing the radiation falling on it and re-radiating it at a different wavelength that shall not be absorbed by the combustion products.
- Crown has to be insulated with care. Over heating the upper surface of the crown by insulating may decrease the creep resistance of the crown.
- To avoid added weight on the crown, preferred crown insulation is ceramic fiber.

Regenerators:

- Regenerators are the special structures which double the thermal efficiency of the furnaces.
- Simple "basketweave" packed regenerators can double thermal efficiency of a furnace.
- Along the length of the regenerators, the type of brick used has to change
  - The topmost layers of the packing must withstand temperatures exceeding 1550 °C and attack by alkali and vanadium of fuel oil, therefore high quality 97-98% MgO bricks are used.
  - At the top meter, this brick is doped with.

- At the band where the temperature is 850-950 °C packing suffers from sulphate attack. Therefore basic bricks with 90-95% MgO are used.
- Use of premixed spinel bricks with higher shock resistance is also possible.
- Furnaces burning heavy fuel oil must substitute MgO with chrome-magnesite which has a better resistance for the H_2SO_4 that shall form..
- At the base of the regenerator where the temperature is around 500 °C, fire clay bricks with 45% Al_2O_3 is used. These bricks are cheep but are susceptible to thermal shock and clogging due to lime and silica settling.

- The efficiency of the packing increases the efficiency of the regenerators.
- The efficiency of a regenerator depends on several factors.
  - Heat capacity of packing.
  - Thermal conductivity of packing.
  - Quantity of packing.
  - Pattern that the packing is laid in.
  - Age of packing.
- Fused cast AZS based corrugated "Crusiform" packing is claimed to give fuel savings typically around 7%. Additionally they:
  - are resistant to any type of creep,
  - are chemically durable,
  - do not clog.
- Insulation of the exterior of the regenerator is equally important
- An effective insulation like sprayed fiber insulation can improve thermal efficiency of a furnace by 5%.

Insulation:

Proper insulation is by far the most effective means of energy saving. It not only decreases the heat losses but also increases the furnace temperatures, accelerating the melting process. A variety of materials are used for insulation at different parts of the system. They are listed below.

- At the regenerators.
  - fire clay insulating bricks,
  - fibre based boards,
  - calcium silicate slabs,
  - expanded perlite boards,
  - fibre based moldables,
  - insulating gun mixes.
- Furnace bottom
  - Insulation firebrick,
  - precast insulation blocks.
- Crown:
  - Silica fiber,
  - ceramic fiber.

- Superstructure:
    - Insulating firebrick,
    - precast insulating concrete slabs.

Oxygen boosting:

Like electric boosting, Oxygen boosting also reduces heat losses from a furnace through three mechanisms.

At 25% oxygen level, there will be 10% fuel economy, with all oxygen firing fuel consumption shall halve.

a)

- A cryogenic oxygen plant spends 2.4-2.5 kcal/Nm3 oxygen.
- Pressure Swing Adsorption requires slightly less energy and is cheaper to install at small scale.

A new developing American system Hollow Fibre Oxygen Enrichment which can get air with 35% O2. It requires low energies and low capital investment

Fuel additives:

Various commercially available fuel additives compositions of which are protected by patents are claimed to decrease the fuel use by 2-3%.

Reduction of primary air:

- 10% primary combustion air of the air utilises 3.5% of the energy input to the furnace is for its heating.
- Burners with no primary air are present.
- They have better heat transfer efficiency due to the increased temperature of the flame.
- Up to 4.5% energy saving can be expected from a burner without primary air.

Control and instrumentation:

Presently, control equipment have concentrated on combustion control because each extra percent of excess air, increases the fuel consumption by 1%. Only oxygen trim control has been recorded to decrease fuel consumption in a 180 ton furnace by 3.6%.

Excess air is controlled by zirconia probes, which have inherent weaknesses. They:

- are expensive,
- are vulnerable to reducing furnace atmosphere,
- are temperature sensitive.
- Their life is variable in a glass furnace.

If this system or previously used "paramagnetic oxygen detectors" could be made more reliable system would be used extensively.

Fully computer integrated, intelligent software systems are available. Such systems have reportedly caused energy savings of 7.7% in the cement industry and 4.5 - 6.9% savings are reported when a 230 ton glass furnace is controlled by a microprocessor without any additional change. But they are not yet in general use.

An intelligent control system named AIMBURN has been developed under European Union ESPRIT programme. Besides monitoring the flame and combustion products. It follows the currents and the batch working like a human operator.

Cullet use:

4% increase of cullet results in 1% reduction in fuel consumption of the furnace. Therefore if suitable foreign cullet is available, it must be used at high proportions.

Methods of collection may change:

- In developed countries, bottle banks
- In developing countries, cullet collecting dealers.

Batch palletising and preheating:

Batch palletising has a multiple effect.

- Avoids batch segregation.
- Batch is dry.
- Melting reaction accelerates.
- Lends itself for direct preheating.

There are two German Companies who produce cullet preheating plants:

- Nikolaus Sorg Gmbh.
- Zippie Industrienlagen Gmbh.

Philips of Netherlands have developed their on system of palletising and preheating batch.

German GEA Energietechnik Gmbh has developed a direct batch and cullet preheating plant for Neinburger Glas Gmbh. For the past 10 years It has been preheating furnace feed to 300 °C and it is reported to have reduced the melting energy from 1154 kcal/kg to 923 kcal/ kg.

Melt aids and glass composition:

- Powerful fluxes like Lithium Oxide and Boron Oxide reduce the overall melting temperature and energy consumption of the furnace.
- Glass forming oxides can be obtained from compounds that contain smaller volatile fraction.
- Additions also change the working properties of the glass.

- With a well tailored batch composition can decrease the fuel consumption of the furnace by more than 10%.

Waste heat boilers:
Many commercial systems are present.

Electric boosting :
Electric boosting reduces heat losses from a furnace through three mechanisms.

- Decreasing the furnace volume.
- Regulation of the back currents in the tank
- Decreasing the volume of combustion products.

Two electrode materials are present:
- Doped tin oxide - is oxidation resistant but has higher electric resistance. Lover current densities are possible.
- Molybdenum. - Oxidizes immediately at high temperatures it must be protected from the atmosphere.

Can be located:
- Horizontally at side wall - is not effected by metal inclusions in glass but less effective.
- Vertically at the bottom - longer life, better convection, higher current densities, easier approach.

Compressors:
Compressed air is the most expensive type of energy. Compressors convert only 10% of the energy they get into the energy of the compress air.
- Use of compressed air must be avoided when possible.
- Never use compressed air if fan air is sufficient.
- Modern screw compressors are more efficient than piston types.
- Compressed air leeks in the factories must not be neglected.
- Compressors must be selected for required capacity.

Electric motors and appliances:
There are special low consumption motors available which consume 4-5% less electricity. They are slightly more expensive then the conventional motors. The difference in price is paid back after 5000 hours of operation.

Even with conventional motors, substantial energy saving can be achieved by following means:

- Motors on equipment must be turned on and off automatically to avoid unnecessary operation.
- Where constant supply is necessary, throttle valves or Variable Speed Drives can be added to the equipment.
- Power factor correction must utilised where there is considerable inductive load on the system.

Over 400-500 hp. Synchronous motors can be used to correct the power factor of the plant.

CONCLUSION:

New materials and new systems are emerging every day. It is for us to follow them continuously.

All producers claim many superiority's of their products. It is for us to judge them.

Energy Conservation in Dielel Generator Set

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Diesel Generating Sets

1.0 Introduction

With the widening gap between the demand and supply of electric power, the role of DG sets in the Indian industry cannot be overemphasized. Depending on the type of industry, its siting and the magnitude of the connected load, DG sets are employed in various modes like (i) standby mode to meet the part or full requirement of the plant in case of power failures, (ii) peak loading mode to meet the requirement during peak demand thereby reducing the maximum demand, (iii) base load mode, where the part or whole of the plant load is supplied on a continuous basis and (iv) total energy mode, where it not only supplies the total power requirement but also meets the heating and or cooling requirement of the plant by utilizing the waste heat from the DG set exhaust in an integrated system.

In this write up, the various aspects related to energy conservation in a DG set are discussed, with specific focus on assessing the operating performance and measures that can be undertaken to reduce the fuel and oil consumption

2.0 Brief system description

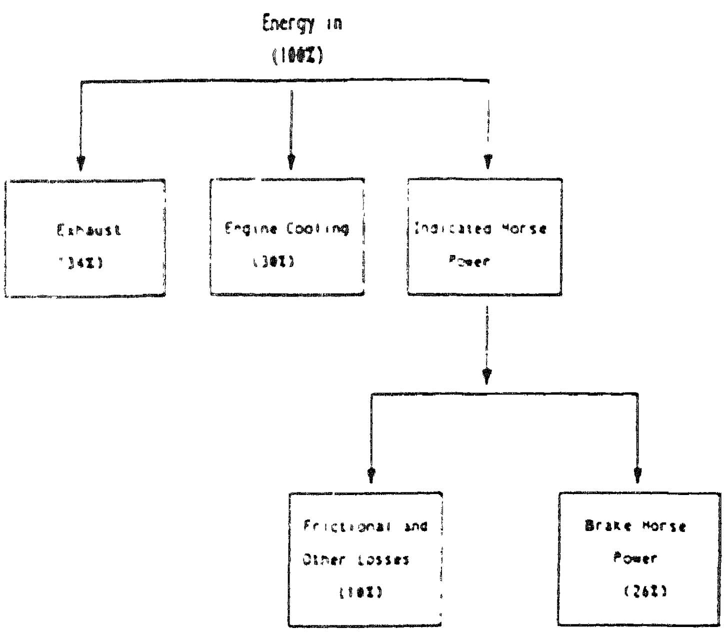
In order to undertake the performance evaluation of a DG set (specifically with regard to energy conservation), some understanding of the system is necessary In this section, some selected relevant details about the system is provided which would help the energy auditor to appreciate the underlying concepts.

DG set consists of a prime mover and an alternator The prime mover, invariably is a compression ignition engine, which depending on its design can run either on high speed diesel (HSD), light diesel oil (LDO), low sulphur heavy stock (LSHS) or other heavier petroleum fractions With the laying out of natural gas pipeline (or gas grid as it is sometimes referred to), and gas being made available to industries, many installations have come up which also utilizes gas, either in dedicated systems or along with diesel in dual fuel operation In the prime mover, the heat energy of the fuel is converted into mechanical energy in the form of rotary motion of the output shaft of the engine The output shaft is directly coupled to an alternator, which generates the electric power So in principle, the DG set consists of two main subsystems an internal combustion engine (most frequently, a compression ignition one) and an alternator For

all practical purposes, while conducting an energy audit of a DG set, it is the engine or the prime mover part, which is concentrated upon.

Internal combustion (IC) engines, generally are considered to be highly energy efficient. This basically stems from the fact that the efficiency level of these engines are substantially higher compared to their predesor, the external combustion engines. But the fact remains that in spite of their relatively superior performance, the efficiency level of a typical engine is only about 26%. As can be seen from **figure1**, of the total energy input (in terms of fuel burnt), 34% is lost through the exhaust, 30% is lost to the cooling medium (coolant) and the balance 36% is converted to useful work, defined as indicated power. Of this 36%, again another 10% is lost as engine frictional and other losses. So out of 100 units of energy that goes into the system, only 26% of it is available at the output shaft. Although the figures given above may vary from one engine design to another, the fact remains that the efficiency level of these engines are quite low as against the general belief. Some of the losses discussed above are, however, unavoidable and are quite peculiar to the basic engine design. There is also a limit to which the efficiency of an IC engine can be improved. The aim of this write up is not to go into the design aspects in deep, but concentrate on items that can be controlled at the users end to affect conservation of fuel and oil. In a system like DG set, more often than not, the end user need to contact the manufacturer for remedy of a particular problem. On the users part, identification of the problem, therefore, assumes a much greater role. In the subsequent sections, the performance assessment along with some conservation options for the fuel and the lubricating oil usage in a DG set are discussed.

Figure 1. Typical energy distribution in an internal combustion engine



3.0 Fuel conservation

In a DG set, reduction of fuel consumption, even by a small percentage can lead to enormous monetary savings. But the first step to approach the problem is to assess the operating efficiency of the DG set. This gives an idea as to whether there is a scope to affect savings, and if so, by how much. The efficiency of a DG set is the combined efficiency of the engine and the alternator. Since it is relatively difficult to compute the efficiency level of the subsystems, the combined efficiency is generally computed. The overall efficiency is, therefore, defined as the number of units of electricity generated per litre of fuel consumption. The resultant figure is called 'Specific Electricity Generation Ratio' (SEGR) with the unit of kWh/lt. Once the above is computed, it remains to compare this with the normative figure supplied by the DG set manufacturer. The recommended level of SEGR values for different sizes of DG sets are shown in table.

Table 1. Recommended SEGR values for different DG set ratings

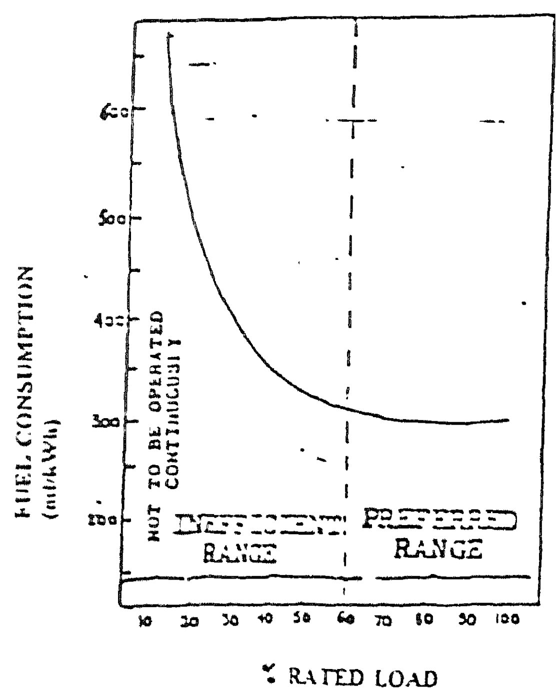
Rating (kVA)	Recommended SEGR (kWh/lit)
1450	3.84
1100	3.88
625	3.73
608	3.50
550	3.50
500	3.84
400	3.69
310	3.30
250	3.20
180	3.07
175	3.0
166	3.0
160	3.0
120	3.0

The single most important component in the above exercise is proper monitoring of fuel consumption for the DG set. It is absolutely essential to have separate fuel measurement arrangement for the individual DG sets to arrive at the correct SEGR value. If the actual SEGR figure is found to be lower than the normative value recommended by the manufacturer, then effort should be made to identify the causes for this deviation. In case the operating efficiency of the DG set is lower than the recommended value, in spite of the engine loading and other operational parameters being within the limits and the periodic maintenance schedule being also followed, it is always advisable to take the help of the DG set manufacturer in this regard. The nature of the problem could range from improper fuel injection (clogged/damaged injectors, fault in the fuel injection pump etc.) to excessive wear in the ring/liner assembly leading to high blow by and subsequent power loss. It is very difficult to remedy some of these faults at the user end and the help of the manufacturer becomes a necessity. There are areas, however, where the DG set user can himself take remedial actions. Some of these measures are discussed below.

3.1 Fuel saving through proper engine loading

The extent to which a DG set is loaded, pronouncedly affects its operating efficiency. At part load operation, the efficiency of the DG set drops down with a consequent decrease in the specific energy generation ratio. The drop in efficiency becomes fairly pronounced at loads below 60% and is a function of (i) the ratio of actual output to rated capacity and (ii) design and capacity rating of the DG set. **Figure 2** illustrates a typical relationship between the extent of loading and the efficiency level, showing the inefficient range and the preferred range of operation.

Figure 2. Effect of loading on the efficiency of dg set



Keeping the above in mind, one must always take care to ensure that to the extent possible, the sets are optimally loaded. Specifically in cases where there are more than one or a bank of DG sets, proper load distribution among the sets can yield rich benefits

3.2 Fuel saving through lubricating oil

As can be seen from the energy distribution diagram in figure 1, the frictional losses are low compared to the input of fuel energy but they form a much more significant proportion of the total useful work. Concentrating our efforts to the mechanical losses part, it is clear that the lubrication is the prime area to improve operating efficiency. The choice of lubricant, therefore, is important and can help in reducing the frictional losses vis-a-vis fuel consumption The single most important oil parameter in this regard is the oil viscosity, which profoundly influences the frictional characteristics of a moving part. Although the viscosity grade of the oil to be used is specified by the DG set manufacturer, some appropriate choices can be exercised in this regard. It is always preferable to use a multigrade oil in place of a monograde oil. Although the cost of multigrade oil is marginally higher than its monograde counterpart, the additional investment in shifting to multigrade oil is justified, on account of its benefits in terms of improved fuel efficiency. Without going into the details of the chemistry of oil formulation, the reason for better fuel efficiency with multigrade oil is briefly discussed below.

Multigrade oils, when first introduced, were primarily formulated to have a wider acceptable viscosity range compared to monograde variety. Which means that the multigrade oil were formulated in such a way that it does not become too viscous (too thick) at low temperatures, nor it becomes very thin (low viscosity) at high temperatures The benefits were obvious. These oils were able to operate over a wide temperature range and avoided the use of (and thereby keeping inventory) different grades of oil for different seasons But in addition to this primary duty, these oils were also found to provide fuel economy benefits, and this is due to the additives used in formulating the multigrade oil. In simpler terms, these additives are polymeric long chain chemical compounds In bearing areas, where there is a high rate of shear, these oils undergo temporary viscosity loss due to the shear breakdown of the long chain additives. This temporary viscosity loss, leads to lowering of the viscous drag, eventually leading to an improvement in fuel economy. The extent of fuel saving possible by this route is of the order of 1.5%.

3.3 *Waste heat recovery*

As has already been explained, about 35% of the total energy input in a DG set is lost through the exhaust gases. Most of the industrial sets of higher rating are, however, turbocharged versions, where part of this energy is utilized in running a turbine, which in turn runs a compressor, delivering supercharged air (air at pressures above than atmospheric) to the engine The resultant effect is improvement in the specific output of the engine. Other major advantage of supercharging is in case of installations at higher altitudes. In these cases, the drop in engine output due to thinner air at higher attitude is compensated by ramming in more air under this mode.

In spite of this, the heat loss through the exhaust gases is quite substantial and can be utilized in specific cases. The recovered waste heat could be used for one or more of the applications listed below.

- Preheat combustion air
- Hot water generation
- Waste heat boiler for steam generation
- Vapour absorbtion refrigeration system

But one thing must always be kept in mind. Waste heat recovery from the DG set is possible only when large quantities of waste heat are available on a continuous basis. Which implies that for DG sets that are run only as a standby, waste heat utilization options will never work out to be economically viable. Only in cases where the set is run on a more or less continuous basis, one can expect a fairly reasonable payback period.

3.4 *Fuel additives*

Fuel additives, generally are used to tackle specific problems, and are resorted to when conventional methods fail. In IC engines, typical examples being, use of carburettor cleanliness additives in case of gasoline engines or the use of additives to counter injector nozzle coking in a diesel engines The claims with regard to additives that can improve energy efficiency in an engine should be weighed very carefully There are fuel efficiency improvement additives available in the market, with manufacturers claim of reducing the fuel consumption by as high as 10-15%. One must review these claims with extreme caution, as the practical experience has shown that invariably, the additives are not cost effective. PCRA (Petroleum Conservation Research Association) carries out assessment evaluation of such additives on a routinely basis.

and it is always preferable to take their advise in this regard Alternatively, the additive supplier should be asked to submit the test/evaluation report being carried out by an accredited laboratory.

4.0 Lubricating oil conservation

For engine applications, the characteristics to be built in the lubricating oil for desirable performance are rather sophisticated and stringent The finished lubricants are, therefore, high value products and need to be used efficiently. The three main ways to achieve lubricant conservation are: (i) through reduction in oil consumption, (ii) by re-refining of used oil and (iii) by optimizing the drain interval.

Reduction in oil consumption is an engine design related subject and there is little that the DG set user can do at his end, except to keep a check on the mechanical condition of the engine. The major routes through which oil is lost are the valve stem to guide clearance and the ring packs. Heavily worn out engines will obviously have high clearances, thereby increasing the oil loss. As a thumb rule, the oil consumption should not exceed 1% of the fuel consumption For modern engines, this value is still lower. If the oil consumption exceeds this limit, the engine manufacturer should be consulted.

Re-refining of used oil is the high temperature distillation and chemical treatment or any other process which removes all undesirable physical and chemical contaminants so as to produce a pure base stock. But it can only be practiced in cases where there is a large number of DG sets and the oil quantity handled is big enough to justify setting up of a re-refining plant. The optimization of the drain interval is something that can be attempted at the user end, some selected details of which are presented below.

4.1 Optimizing oil drain interval

Crankcase oil needs renewal because it receives contamination from the atmosphere, soot, unburned fuel and sulphurous acid from the blowby products and gets oxidized in service due to exposure to heat, and air Apart from these, the oil also loses its potential due to depletion of the functional additives. An optimum oil drain period represents the best compromise between the safety of engine parts and the economy in quantum of oil required over a specified hours of operation.Oil in service is drained after fixed hours of operation, based on the recommendation of the engine manufacturer. These recommendations are broad based, bearing very little correlation with the actual state of the used oil So the situation calls for monitoring the quality

of oil in service regularly and draining it only when it is found unfit for further use. The quality of the oil can be judged on the basis of following parameters:

(i) Viscosity change
(ii) Flash point
(iii) Insoluble build up
(iv) Neutralization value
(v) Water content and
(vi) Silica content

It is always advisable to consult with the oil supplier to decide the discard limits of the above oil parameters for specific applications. The discard limits shown in **table 2** can be taken as a rough guide for HD type 3 oil (servo Super grade of IOC).

Table 2. Rough guide for the discard limit of type 3 oil

Oil characteristics	Limit for change of engine oil
Flash Point	180 C Minimum
Viscosity Change	+/- 25% at 100 C
Pentane Insolubles	5% Maximum
Water Content	0 2% Maximum
TBN (Total Base Number)	1 5 Minimum
Silicon	20 ppm Maximum

Some of the critical parameters of used oil could be monitored at regular intervals and the oil be discarded only when it reaches/approaches the discard limit. There are many instances - both in stationary as well as mobile applications, where oil charge based on condition monitoring of used oil have yielded much benefits.

Energy Conservation in Glass Melting Furnaces

C V Chalam
Chalam Consultants

ENERGY CONSERVATION IN GLASS MELTING FURNACES

It is now well realised all over the Globe that the bounty of Hydrocarbon fuels - Coal, Oil and Gas which biology and geology contrived to trap millions of years ago is limited and it is not being replaced. Future generations would be shocked to realise that their ancestors in the 20th Century used up and wasted a large bulk of the exhaustible energy endowment in industry including the Glass Industry. As we enter the 21st Century we face bleak reserves of Fossil Fuels.

The Energy Supply :

Coal was the main fuel used in the Indian Glass Industry in the early part of the Century though some glass melting furnaces in Western coast and Bengal have been using imported Fuel Oil. With the deterioration in the Quality of coal with increase in Ash content and rising costs most of the units using coal earlier are shifting over to fuel oil or natural gas where it is available.

A number of small direct fired pot furnaces and producer gas fired tank furnaces still use coal as fuel.

ENERGY CONSERVATION

As the cost of energy constitutes a permanent incentive to the search for energy savings, Energy conservation programme in the glass industry is a continuing activity. With the oil shock in the Seventies developed countries took up Energy conservation in glass melting furnaces seriously and achieved a remarkable reduction in fuel consumption per unit of glass melted. India was rather slow to react to the situation and took up Energy Conservation seriously only towards the end of the last decade. The Industry did achieve improvement in fuel consumption since then. A vast potential however still exists for reduction in energy costs.

1. Energy forms a significant part of the cost of production and warrants priority attention.

2. Energy savings potential is substantial.

3. Energy conservation will bring quick results.

4. Energy savings are measurable.

5. Energy conservation makes the industry competitive.

In all branches of the Glass Industry vigorous and effective endeavours have resulted in notable energy savings These efforts were indispensable, in order to ensure that firms were competitive and profitable despite constantly rising energy prices. The firms used varying means, depending on the country and their special situation

The basic energy conservation projects in a glass melting furnace are :

1. Control combustion air, reduce excess air or eliminate combustibles in flue gases as the case may be.

2. Insulate the furnace bottom, sides, superstructure, crown, heat recovery chambers and flues.

Identified savings potential by insulation		
AZS Fused cast side walls	-	87.5%
AZS Fused cast superstructure	-	79.0%
Multi-layer bottom	-	71.2%
Silica Crown	-	51.3%
Average	-	72.25%

3. Eliminate cold air infiltration and sting outs.

4. Upgrade firing equipment.

While insulation reduces fuel consumption, precautions must be taken to ensure that the refractory materials withstand the resultant higher temperature and do not cause glass leaks through the bottom and side walls or cause crown subsidence.

Improvement is continuously being done by oil or gas burner manufacturers for improved efficiency after considerable development work and renewal of burners with improved versions result in considerable reduction in fuel consumption

By 1990 the glass industry reduced the fuel consumption by about 10 to 15% on the average over the figures attained in 1981.

Scenario of Energy Savings in EEC Countries in the eighties projects the potential of Energy Conservation

Measure	Saving in PJ	As % of 1981 consumption 170 PJ	Action necessary
Recycling of container glass	2.0	1.2	Identification of national promotional campaigns and investment
Light weighting of container glass	9.0	5.3	Development and investment
Flame furnaces	16.2	9.5	Development and investment
Electrical melting	5.0	2.9	Development and competitiveness of electricity prices
Secondary recovery of the secondary heat from waste gas (For the preheating of the batch of the production of electricity)	1.1	0.7	Development and investment
Forehearth	0.2	0.1	Investment
Forming machines	1.2	0.7	Investment
Annealing lehrs	0.3	0.2	Investment
Total	35.0	20.6	

Source On the basis of extrapolation of the savings achieved in 1973-81.

Energy savings on the raw materials in the Container Glass Sector through recycling was estimated at 3.4 PJ.

These will be generated if national promotional campaigns are intensified and adequate investment is made.

It should be remembered that all energy saving possibilities described here cannot be implemented in all the sectors on account of technology or for reasons of quality

Further importance of energy savings varies from country to country within EEC since the prices of energy - electricity vary from country to country.

The often very substantial investment on energy savings and the resulting economic calculations constitute in the final analysis the most important criterion for firms with regard to further projects of energy conservation.

The possibilities for further energy savings are comprehensible if these comments are taken into account, from which it can be assumed that every firm in the glass industry wishes to save even more energy in the future too.

A large potential exists for energy conservation in the Firozabad area where modern technical control and operations is yet to be established.

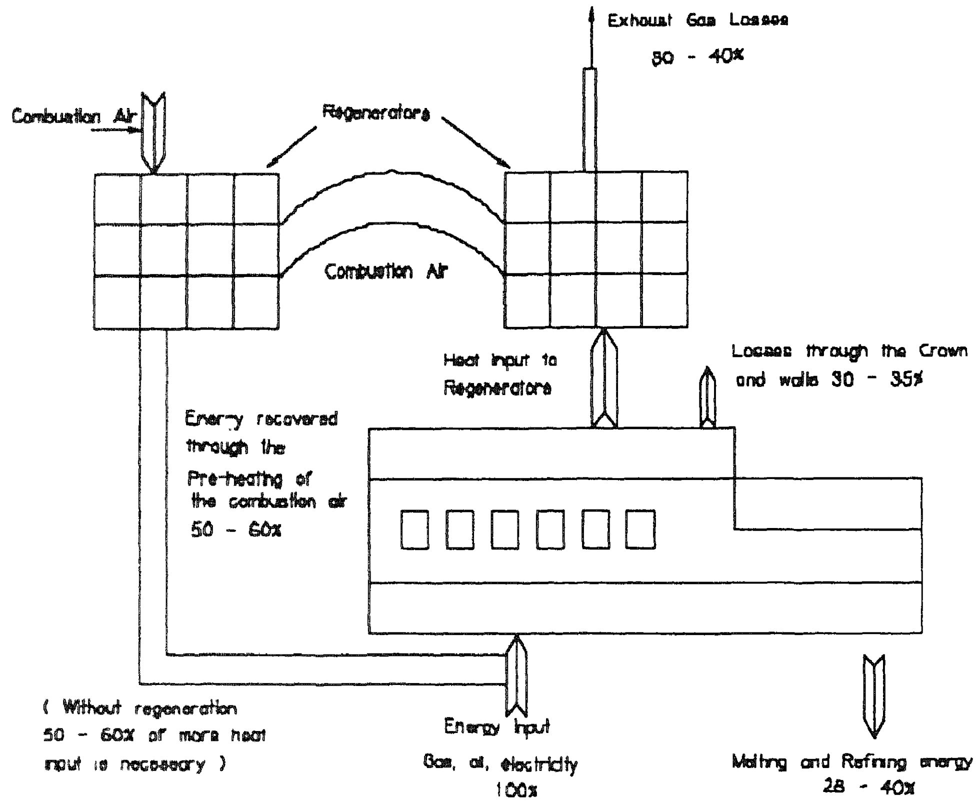
ENERGY BALANCE

The largest proportion of the energy is used in melting and refining in all the three sectors as follows :

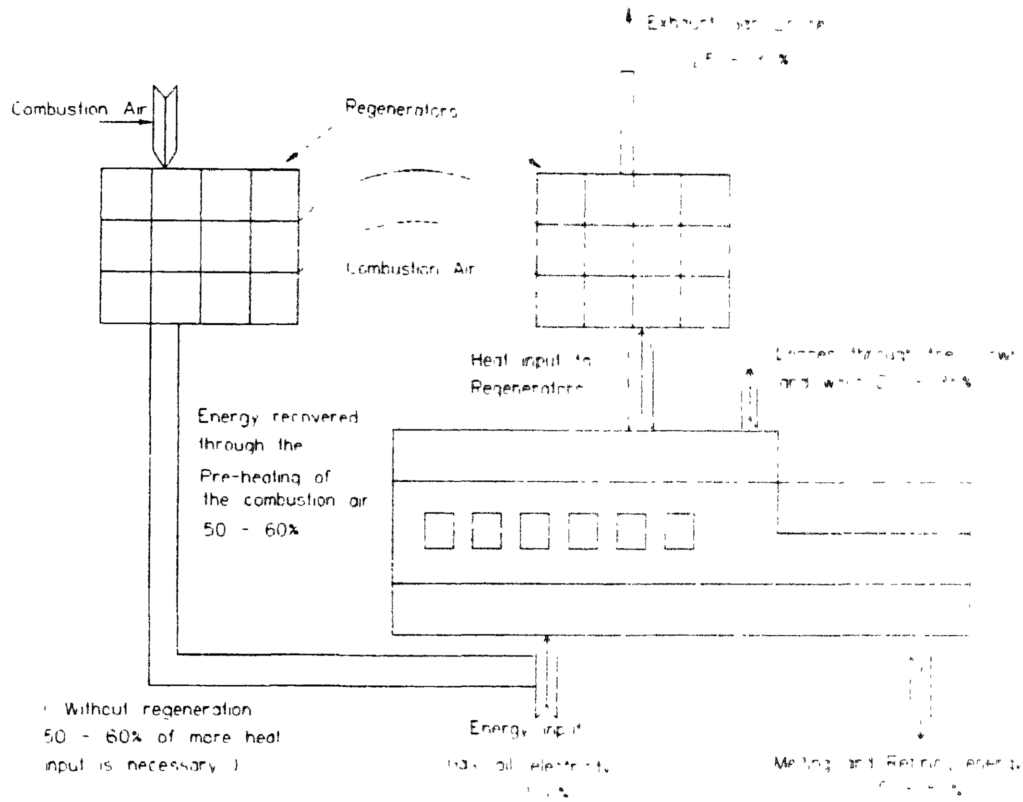
Flat Glass	-	85 to 90%
Container Glass	-	80 to 85%
Glass Fibres		
• Insulation	-	50 to 60%
• Reinforcement	-	55 to 65%

This means that the greatest potential for energy conservation lies in this division. A critical study of energy balance indicates where energy is lost and where energy can be saved.

An example of Energy balance of a flat glass regenerative furnace.



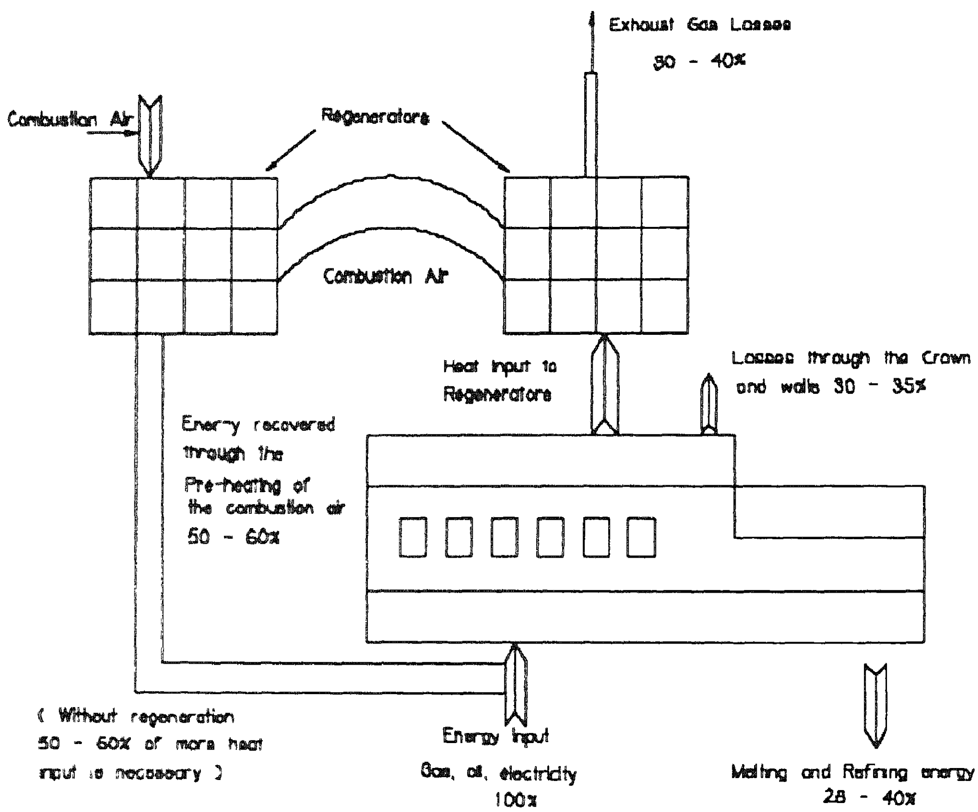
An example of Energy Balance of a Container Glass Furnace :



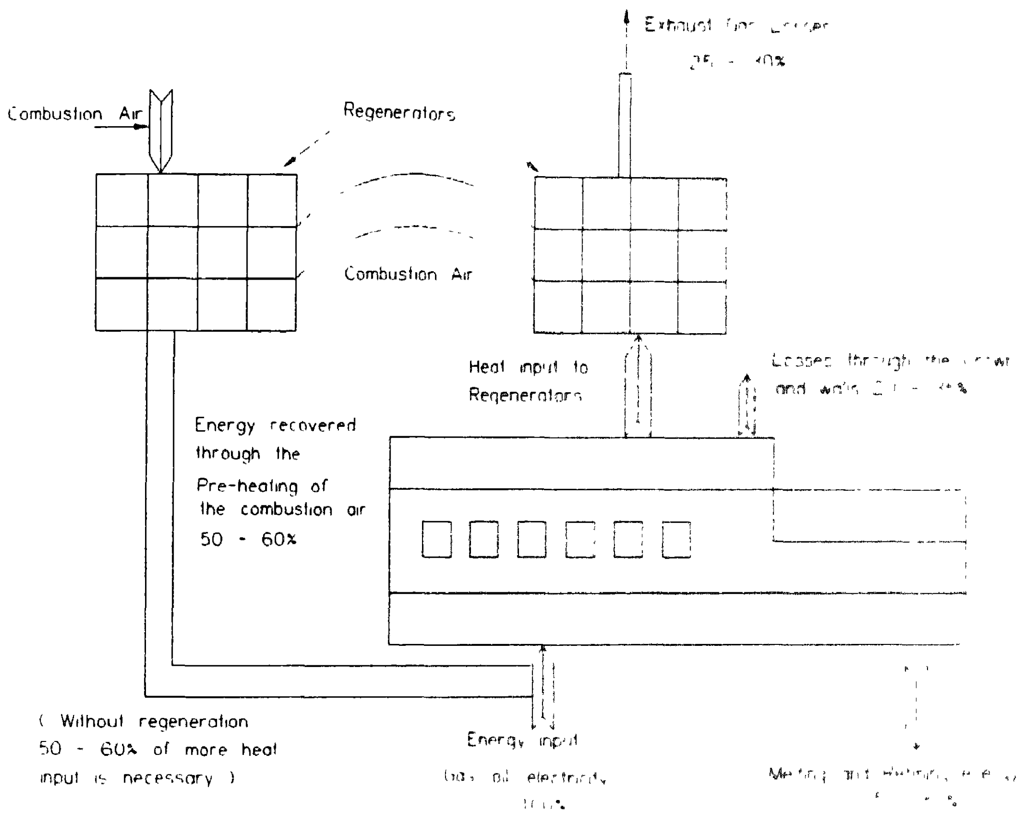
The energy balance would be different for different types of furnaces and different loads.

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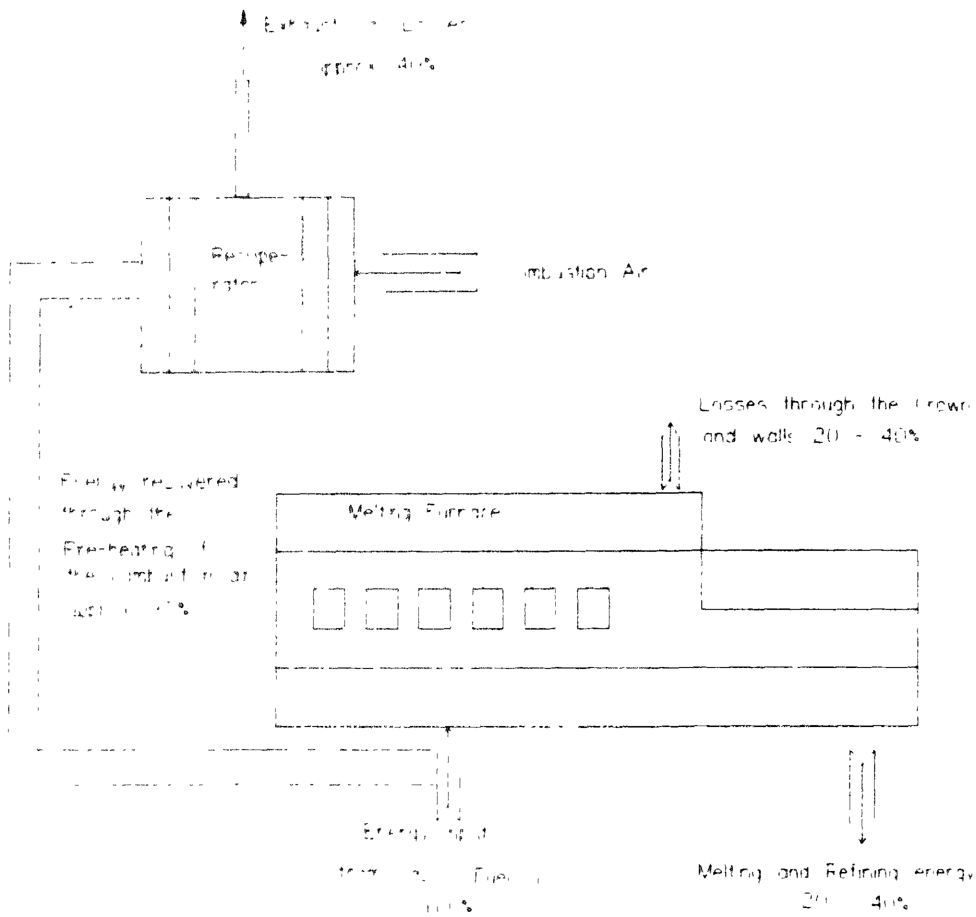


An example of Energy Balance of a Container Glass Furnace :



The energy balance would be different for different types of furnaces and different loads.

Recuperative Furnace



Recuperative furnaces are used in fibre glass and container industry.

20 to 40% of heat is lost through the crown and walls and around 40% in the exhaust gases escaping through the recuperator chimney.

From the preceding energy balances of the three sectors suitable schemes can be developed for energy conservation.

Not all the measures have the same importance in all countries. Introduction of electrical energy to replace oil or gas to achieve energy conservation would not be appropriate in countries like India where electrical energy is highly costly compared to oil, gas or coal per unit input of heat energy.

By practising energy savings a reduction in energy cost amounting to 5 to 45% could be achieved.

PROJECTS FOR ENERGY SAVINGS IN MELTING

a) Increased use of cullet

b) Improvement of the batch for

   i) lowering of melting temperature

   ii) speeding up of melting process.

c) Improvement in the design of the furnaces to improve thermal efficiency

   i) improved insulation of furnace and regenerators which reduces heat losses from the surface by reducing the cold face temperature.

   ii) Bigger furnaces - The proportion of heat losses to the useful heat is reduced in bigger furnaces. In other words the surface area per unit of glass melted is lesser in bigger furnaces resulting in lower radiation losses per unit of glass melted.

   iii) Improved design of larger furnaces raises specific melting capacity e g 3 to 3.5 tonnes per sq. metre per day against 2 tonnes per day per sq metre in small furnaces.

   iv) Electric melting or electric boosting in totally fuel fired furnaces.

   v) Substitution of sheet glass process by the float process where yield is higher and specific heat consumption lower.

d) Improvement in combustion control and management of the furnace in order to obtain required useful energy with less fuel.

   i) better atomisation of fuel.

   ii) using natural gas where available instead of compressed air for atomisation.

   iii) optimum flame length and regenerator reversal cycle.

   iv) reduction of cooling air for the burner.

   v) accurate control by computerisation.

e) Increase in yield between batch and finished product

   i) reduction in changes in production - types of ware, capacity, pattern, thickness etc.

   ii) improved quality by elimination of all factors contributing to a loss in production due to poor quality.

   iii) improved controls to quickly identify quality defects, immediate analysis and rectification.

f) Higher secondary recovery of heat from the combustion gases escaping through the chimney :

   i) utilisation of waste heat potential by means of more efficient heat exchangers.

   ii) preheating of the batch / cullet with exhaust gases.

ENERGY SAVINGS OUTSIDE MELTING

i) Improvement of the design and use of better refractory materials for the working end, the side channels and feeder channels.

ii) Recovery of waste heat from working end, side channels and feeder channels by means of recuperators to preheat the combustion air. In cold countries recovered waste heat can be utilised for heating buildings.

As an example improvement in specific energy consumption in various glass sectors in EEC Countries are given below :

Sector	1970 - '73	1981
Flat Glass	17.5 GJ / t	12.3 GJ / t
Container Glass	12.7 GJ / t	10.4 GJ / t
Insulation Glass fibres	32.9 GJ / t	30.5 GJ / t
Reinforcement Glass fibres	56.5 GJ / t	31.5 GJ / t

Electric melting results in a reduction in specific energy consumption but may not result in a reduction in cost of energy per unit production.

The main objective of the manufacturer is to reduce cost of production. Energy conservation should not be at the expense of quality or total cost of saleable production.

Energy Savings in the Batch :

i) Extensive use of cullet in container and figured glass industry

ii) Use of additives such as calumite (blast furnace slag) and spodumene.

Use of Cullet :

Purchased Cullet added to the batch improves melting and reduces required heat input.

Care must however be taken to ensure that quality is not affected.

Purchased cullet must be properly selected, cleaned and washed if necessary before feeding into the furnace. It can be used in hollow-ware or figured glass, glass tubes or lamp-ware.

Caution :

Tramp metal caused considerable damage to the bottoms in insulated furnaces (insulated bottoms) more so where bubblers are used leading to a failure in extreme cases.

Normally a minimum cullet ratio of about 20% is necessary for good melting.

With more glass manufacturing units resorting to higher proportions of purchased cullet availability of this commodity has become scarce. The purchase department has to be active all the time in identifying sources of cullet supply and procure as much cullet as possible at an affordable price.

With 20% as a basis it should be theoretically possible to increase it right upto 100% provided the composition is the same as the target (which normally is not possible).

Correction must be made in raw material batch to compensate for any variation in composition of purchased cullet from target composition.

At higher percentages of cullet however reduction in energy is not always proportional to the percentage of cullet.

The constraints in using higher percentage of cullet are :

i) Quality standards

ii) Deleterious effect of metal caps and tramp metal on corrosion.

iii) Foreign bodies which can enter the furnace as a contaminant (Porcelain, ceramics etc.) cause inclusions in the form of stones causing rejects.

Market standards for colour have to be met. At high cullet percentages the colour of the glass may vary from the standard.

Only Emerald and Dark Green can absorb very large proportion of mixed cullet

The energy saved on glass melting through the use of cullet is estimated to be 1.5 GJ / tonne of foreign cullet charged.

Investment required to use increased qualities of cullet is only for inspection, cleaning, washing and handling.

The recycling of used glass containers is directly linked with 'production - consumption' of beverages and food stuffs economic cycle.

The savings made can be estimated by taking into account

i) the initial and processing cost of the raw material which cullet replaces.

ii) the collection of glass recycling, its treatment and delivery to the glass works and the electrical consumption in the glass works. The use of cullet results in a saving in energy used in mixing or extraction, processing such as crushing, beneficiation and transport. The savings made in this sector works out to around 2.5 GJ per tonne. This in 1982 accounted for 125 kt oil equivalent (5 PJ) out of a total of 200 ktoe (8 PJ) saved in the EEC as a result of recycling.

The recycling in container glass waste constitutes an industrial sector in itself using

i) as raw material - household and industrial waste glass.

ii) energy

iii) treatment plants

iv) labour.

It manufactures a product - foreign cullet - which in its use by the glass industry will produce large scale savings in the overall context of the 'production - consumption' of beverages and food stuff.

The total energy saving achieved by use of one tonne of recycled glass is
100 kg fuel oil / t or 4 GJ / t.

Energy Savings made through Glass recycling

Country	Tonnage of glass recycled (1000 t)				
	1979	1980	1981	1982	%
F R G	310	480	673	750	28%
Belgium	100	100	100	100	33%
Denmark	12	12	20	21	10%
France	220	336	416	478	22%
U K	30	55	85	110	6%
Ireland	5	5	6	7	8%
Italy	nd	320	350	355	21%
Netherlands	nd	nd	175	200	47%
Total (kt recycled glass)			1825	2021	
Energy Savings in tonnes oil equivalent			182,500 t o e	202,100 t o e	
in Peta Joules			7.3 PJ	8.1 PJ	
Variation / Previous year				+ 11%	

Source : Federation European du Verre de Emballge feve.

In India we have very modern glass melting furnaces with melting capacity of around 500 tons per day, hi-tech furnaces melting high quality glasses in electric melters on the one hand and very crude furnaces melting glass in direct coal fired furnaces.

Each furnace will have to be studied in detail to identify a most appropriate energy conservation programme.

The technology and technical knowledge of glass melting furnaces is fairly good and some of the units in India are comparable with the best in the World, though on the average we have to go a long way to catch up with the developed world.

We should also remember that Energy Conservation is a continuing action and the industry should not slacken its efforts on this very important activity.

A survey by National Productivity Council identified a savings of around 1400 tons of Furnace oil valued at over 84 lakhs rupees at that time in an individual glass manufacturing unit.

THE APPROACH

A Melting Energy Conservation Programme (MECP) will have to be initiated.

Normally the operating executives are busy all the time keeping up and improving the saleable yield. A senior executive of the development wing will have to be assigned this particular programme.

The first step is making an energy audit. This can be done either in-house or employing external specialists or energy consultants who have all the required knowledge and equipment to conduct an energy audit.

The energy audit would cover

i) Measurement of surface temperatures of the refractory surfaces and in all the areas, estimate radiation losses.

ii) Analyse flue gases and estimate excess air or presence of combustibles.

iii) Identify all openings in the furnace structure at the raw material filling points, firing areas, sight holes etc. and estimate heat loss by sting outs or entry of cold air.

iv) Observe operating parameters namely temperature profile, furnace pressure, variation of glass level and flame lengths.

v) Fuel handling covering receipts, storage, distribution and quality.

vi) Control equipment and condition of instrumentation, reliability and its maintenance.

vii) Cooling air, its pressure and volume at all the points.

viii) Study the detailed drawings of the furnace.

ix) Details of firing system - rate of flow of through each burner, condition of the burner, if fuel oil is used its temperature, viscosity and variation of viscosity.

x) Cullet ratio.

xi) Batch composition and grading of all the raw materials.

Based on the above a detailed report would be presented to the top management detailing the following :

1. Energy conservation projects which can be implemented immediately on the operating furnaces covering :

    i) Combustion air control.

    ii) Instrumentation maintenance and improvement.

    iii) Adjustment in burner position and burner angles if required in Fuel oil or natural gas fired furnaces.

    iv) Adjustment of heat input through different ports in cross fired furnaces

    v) Sealing up air infiltration and sting outs.

    vi) Introduction of melting aids such as Calumite and Spodumene if advisable.

    vii) Increased cullet ratio.

    viii) Modify grading of the raw materials if required.

    ix) Changing firing equipment with improved type if warranted.

    x) Installation of cullet and batch preheating with flue gases

xi) The energy audit would recommend upgradation or alteration in the furnace design which would raise combustion air preheat temperature, reduce structural heat losses and result in overall reduction in fuel consumption at the time of cold repair.

In all the above projects the costs involved, estimated reduction in fuel cost and pay back period would be estimated. The first eight projects would not cost much and results can be noticed immediately

Cost estimates of major alterations or modifications in the design of the furnace would also be worked out backed up with firm quotations of refractory materials, firing equipment etc.

Whatever projects are cleared for implementation the MECP team would follow up with implementation of the projects.

As the projects are implemented they should be continuously monitored, causes of variation if any remedied and energy cost reduction achieved.

To take up energy conservation seriously, comparison should be made with the best operating glass melting furnaces from all over the World. Energy analysis covering utilisation and losses of the furnace under study should be compared, lapses identified and remedial action in operation and design of the furnace identified.

Substitution of alternate cheaper fuels (cost per million Kilo calories) would mean a lot of energy conservation.

At least in two well known flat glass manufacturing units the profitability of the company improved substantially by substituting fuel oil with coal.

Problems are there with poor and varying quality of coal, high ash content etc but with a strong determination and perseverance they can be solved.

Energy conservation is simple, well proven and all that is needed is willingness and determination to achieve saving.

Energy costs call for closer scrutiny as they form a significant portion of the cost of production. They must be controlled to avoid erosion of profit margins.

Energy conservation generates energy savings and makes the industry more competitive. The company has to pay increasing attention to training, auditing, accountability for results, better maintenance, increased supervisory and operator attention and upkeep of instrumentation.

Oxy-fuel is the latest concept and it has resulted in energy savings besides reducing NOx pollution. In India, however, the savings in energy cost is more than offset by the high cost of Oxygen. Oxygen cost is continuously being improved and Oxy-fuel may work out economically viable in the first decade of the next century. New entrants in the glass manufacturing activity would be benefited to go in for Oxy-fuel as the high cost of regenerators can be eliminated from the project cost and oxygen plant vendors have offers to put oxygen generating units at their cost at the site of projects under implementation.

CASE STUDIES

1. Reduction of Excess Air

   In a lamp glass melting furnace the oxygen in flue gases was reduced from 4.8% to 2.5% which resulted in a saving of 5 litres of Fuel Oil per hour valued at annual savings of around Rs.25 lakhs.

2. Closing sting outs

   In an oil fired glass melting furnace an opening of 6.5 cm x 11.5 cm caused a heat loss of 51000 K.Cal / hour. By closing the opening fuel consumption could be reduced by 5 litres per hour or 432 KL per annum valued at Rs.25 lakhs.

3 Substitution of Cheaper Fuel

   A small size Sheet Glass Works in late Seventies.

   Using 22.3 KL Fuel Oil / day costing Rs.6.9 lakhs per month.

   From December, 1977 when gas producers were commissioned and a small quantity of oil was put in the last port for refining.

   The monthly fuel consumption was 96 KL Fuel oil + 1491 tonnes of coal costing Rs.4.6 lakhs.

   There was a thus positive saving of Rs.2.3 lakhs per month on the fuel bill not a small amount in 1977. The saving in fact amounted to around 38% and the pay-back period was about one year.

   This in fact contributed largely in turning the Company from a loss making one to a profit making one.

Energy Conservation by Modification in Annaealing Lehrs

R Chandra
Shamvik Glass

ENERGY CONSERVATION IN ANNEALING LEHRS

Glass Industry has gone through numerous improvements in past three or four decades and industry in India is trying to keep abreast with the developments in advanced countries.

Looking back to scenario of semi-automatic and mouth blown glass ware the Annealing chambers were coal fed and came coalfired Lehrs which used to accommodate hand pulled trays in which ware used to be stacked and gradually pulled from hot end to cold end. Oil fired Lehrs then came into picture replacing coal. These Lehrs can still be seen in operation in some of the old units.

All electric Lehr then came in Glass Industry. Auto temperature control were introduced. The people operating them very happy due to handy neat controls and ware free from soot/combustion deposit. They included recirculating type as well

With the introduction of all Electric Lehrs, greater emphasis and stress was laid on good quality insulation, temperature controls and improvement on cold end inspection.

Greater stress was laid on sophisticated instrumentation and temperature control, maintenance of electric heaters and insulation. Variable speed drives were then introduced to control the belt speed which had to be adjusted according to ware being manufactured at the forming machine.

The operating personnel were constantly monitoring the energy consumed in Lehrs and energy meters were fitted and reading monitored on daily basis. The energy consumed reflected various parameter which were responsible for the ultimate reading.

These were

- Opening of Dampers
- Type of ware being fed in Lehr
- Belt speed
- State of insulation
- State of heating equipment

With the location of Glass factories coming up in the natural gas belt, where piped gas supply come from mother earth and also other factories which has storage of LPG, Gas fired Lehrs came into existence. Certain Lehrs also had electric heating elements for slow heating to start with and later change over to gas firing.

Latest gas fired Lehrs are now available which are energy efficient and have replaced electric Lehrs in some modern plants just like any other gas fired forehearth/Furnace. The controls are very sophisticated and need very high standards of maintenance.

The energy consumed in these Gas fired Lehrs is monitored on daily basis.

Some Plant lowered the tunnel height of Lehr from 20" to only 6" to 12" to accommodate bottles of particular height on such Lehrs. This gave fantastic results in saving energy.

Lehr are specifically designed to accurately meet the annealing requirement for various type of glasses.

Sodalime
Borosilicate glass
Lead crystal glass
Barium glass for TV tubel
Opal glass

Lehrs come in various widths depending on production utility, viz. 4 feet, 6 feet, 8 feet, 10 feet and 12 feet width. These could be designed as per customer's requirement.

Radiant and Recirculated Lehr
Radiant Lehr
Fully recirculated Lehrs

- Heating capacity of Lehr is designed to suit the Lehr capacity.
- Modular construction incorporating automatic temperature controls for annealing and decorating
- Specially designed recirculating fans which are statically dynamically balanced
- Sturdy belt drive incorporating variable speed drives for accommodating belts speeds of 4' to 24 feet per minute
- Easy replacement of zones for maintenance purposes
- Computerised interface controls
- Adjustable zone damper
- Smooth return belt arrangement
- Controlled cooling in cooling zone
- Provision for accommodating longitudenal expansion.

CERAMIC FIBRE INSULATION

When installing new insulation or when retrofitting existing equipment, one should consider using ceramic fiber blankets instead of conventional fire brick. Ceramic fiber offers distinct advantages :

- It has only one-third to one-half the heat conductivity of fire brick and may be installed in correspondingly thinner layers for a given heat loss.
- It has a heat storage capacity of approximately one-tenth that of an equivalent layer of insulating brick. This feature saves both energy and time in start-up, or in reheating during a batch cycling operation.
- It is immune to failures by spalling or cracking due to rapid heating and cooling.
- Its light weight makes it possible to install it without major rebuilding of a furnace.

It likewise has some disadvantages :-

- Since it is very poor in physical strength, it can not be installed on furnace floors or in other areas where it would be subjected to mechanical abrasion.
- Since its insulating properties depend on its high porosity, its use should be questioned in any service where the pores might be plugged up by deposits from fumes or by particulate matter.
- It is intended for installation on the hot side of furnace walls or roofs. A blanket of fiber on the cold side of an existing furnace wall may cause some of the interior layers of brick to heat beyond their useful service temperature.

RADIATION LOSS

S.No.	Temperature	Energy Loss Btu/sq.ft. per hour	Loss in Kilo watt per Ft.Sq.
1.	555°C	8000	2.35
2.	833°C	20000	6
3.	1115°C	52000	15
4.	1400°C	125000	36

MISCELLANEOUS ENERGY CONSERVATION OPPORTUNITIES

There are many practices and procedures that waste energy but go unnoticed because "we have always done it this way". This listing cannot pretend to be exhaustive, but covers some of the more important points. Note that these practices are apt to be those that were started when the cost of energy was rather unimportant.

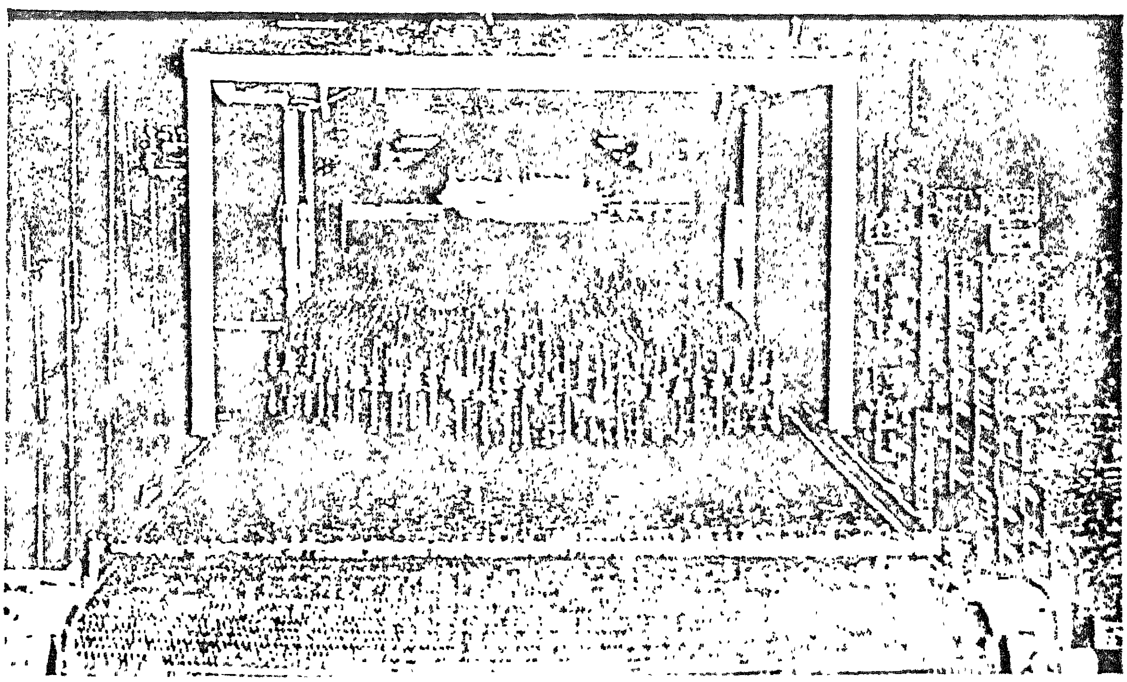
1. Over specification on part of designer due to an early desire of large factor of safety and to reluctance to change something that is working.

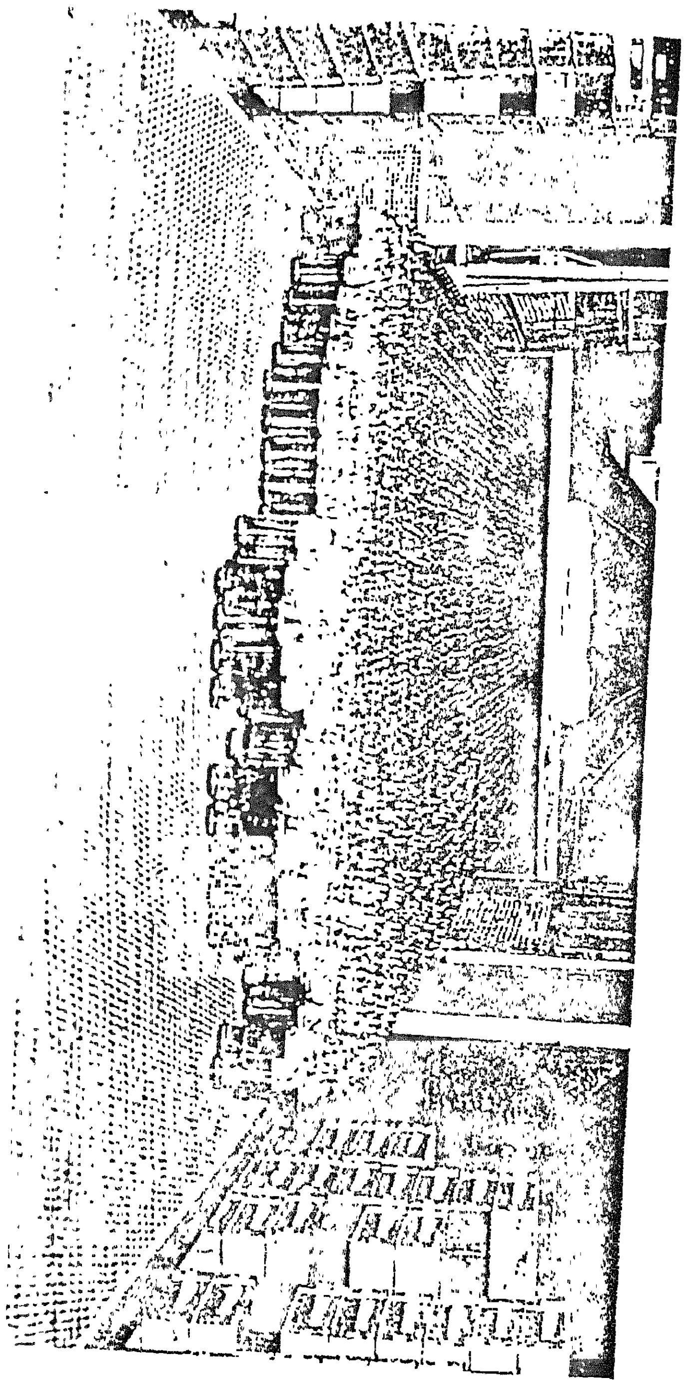
2. Prod. people are sometimes guilty of energy waste. Proper care has to be paid to adjustment of Lehr from done and zones adjustable dampers. Cold wind draught from the front door can cause lot of waste heat. It is advisable to install a "Jhallar" type screen on the front through which bottles can pass.

3. Avoid putting any metallic item viz. Trough, Scoop, Deflector in Lehr for drying the coating. It is detrimental to belt as well as it is a bad practice.

   Lehrs are designed by the equipment manufacturer as per requirement of the plant. It is important that the control equipment and optimised operating procedures be remembered and personnel maintaining them be trained; otherwise the performance including energy conservation levels will be effected adversly.







PUTTING IN PLACE OF THE SECTIONS

CNUD's drawing n° 8078.312.

This drawing shows accurately the location of each lehr section, giving the required space dimensions.

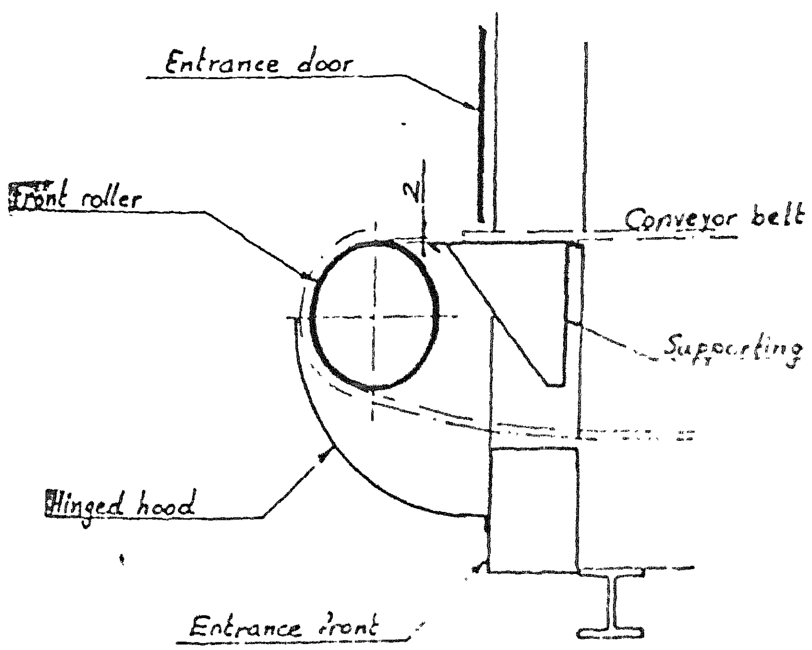
MOUNTING OF THE 1st SECTION WITH ENTRANCE FRONT

1º Bring the section with the entrance front at the immediate proximity of the reference line.

2. Fix the entrance door on the front (see pages 06/01 a and 06/01 b)

3. Mount the front roller with its bearings, adjust it 2 mm above the belt supporting grate

4. Mount the hinged hood on the entrance front (see page 06/01 c)

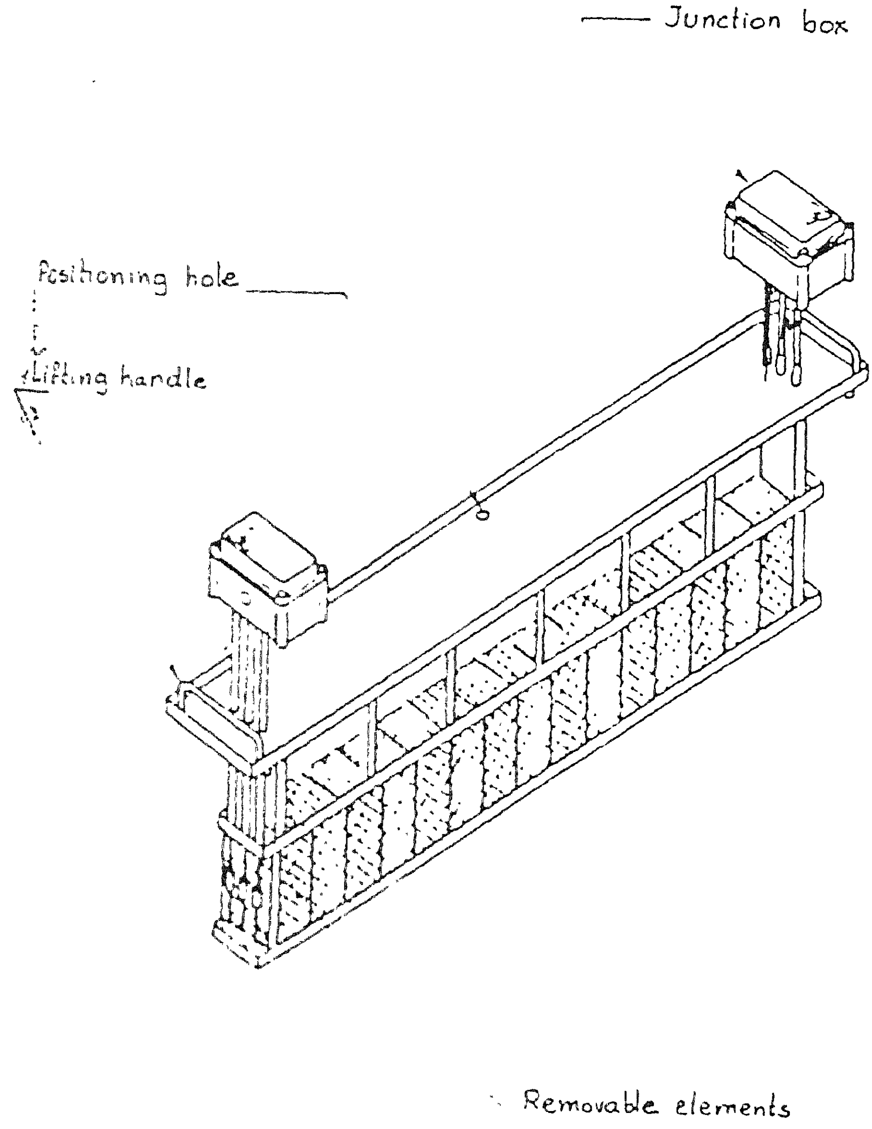


ELECTRIC HEATING

HEATING BOXES

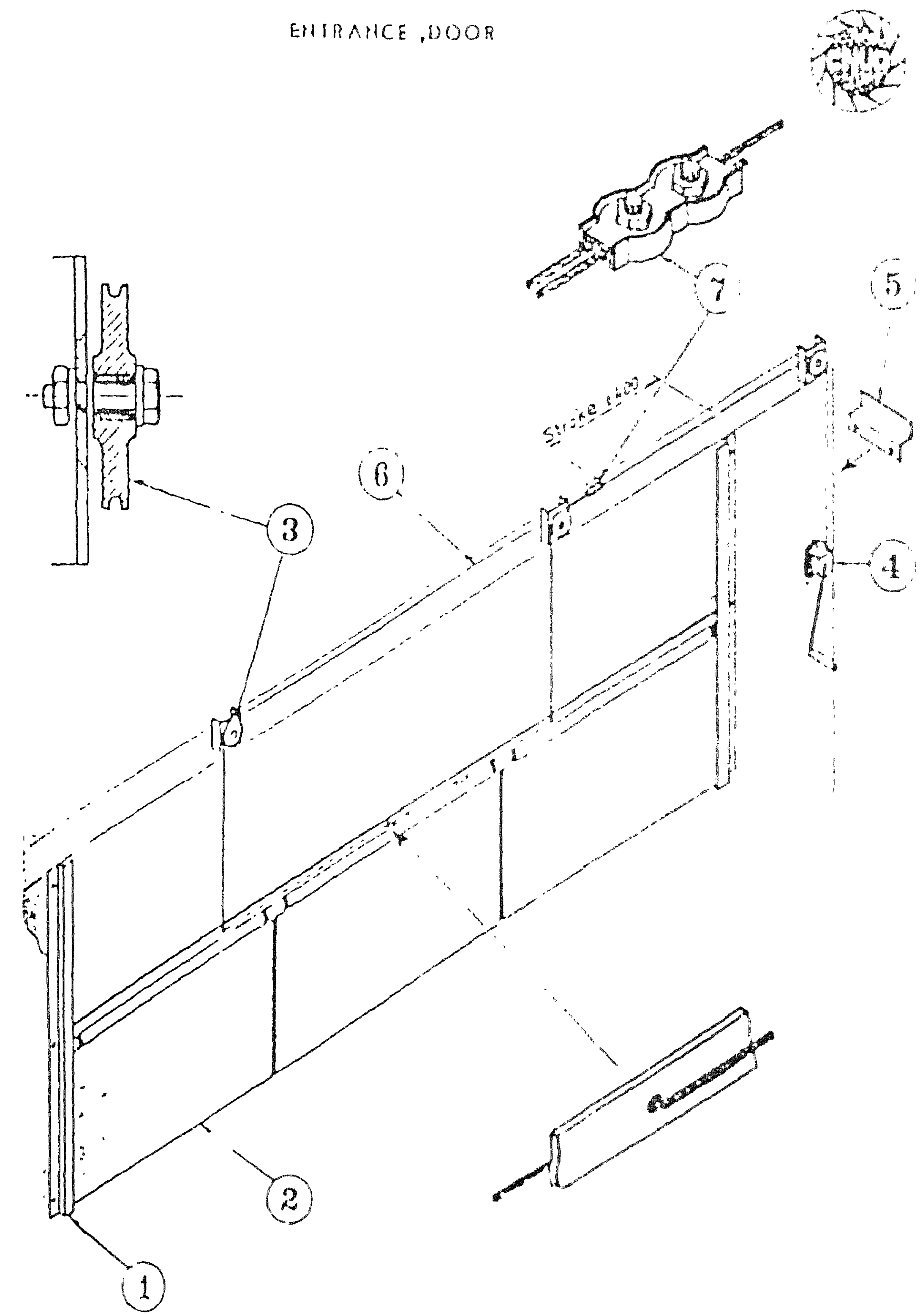
The heating elements stay in the sections for transport.

Dismounting



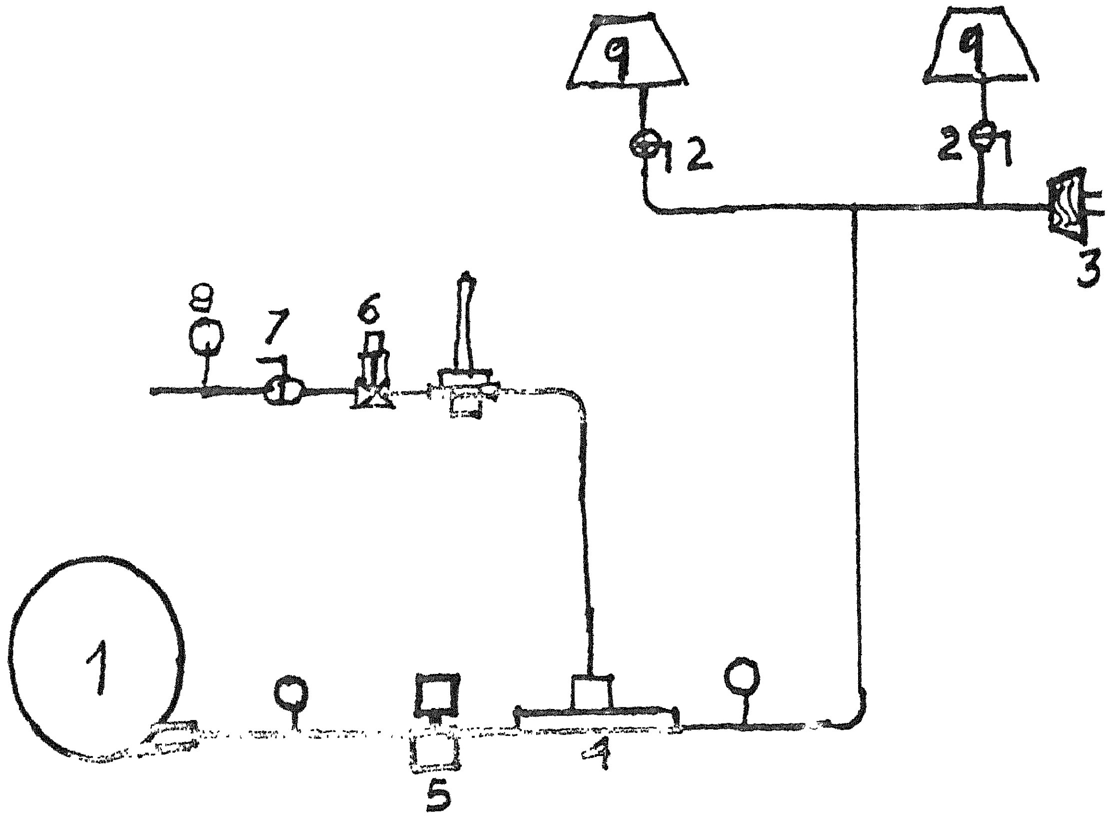
Maximum weight About 75 kg for a heating box of 66 kw

ENTRANCE ,DOOR



Typical Piping diagram

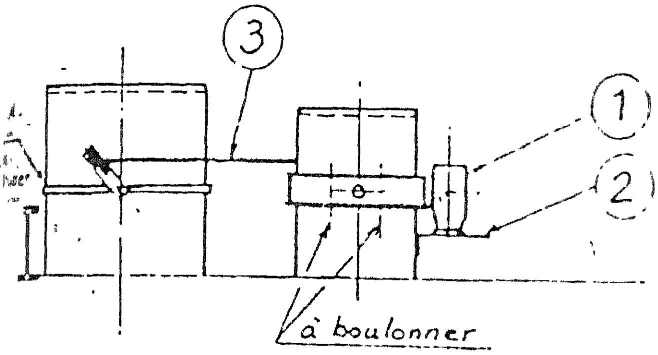
AIR / Gas

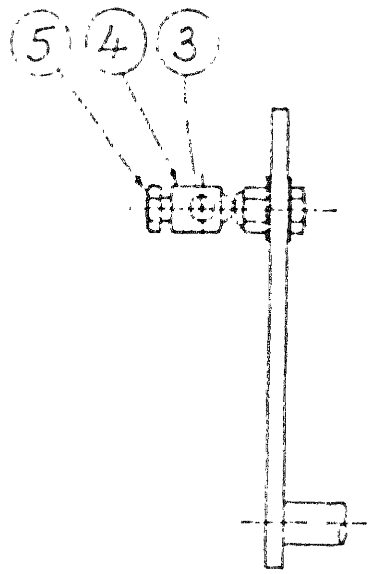


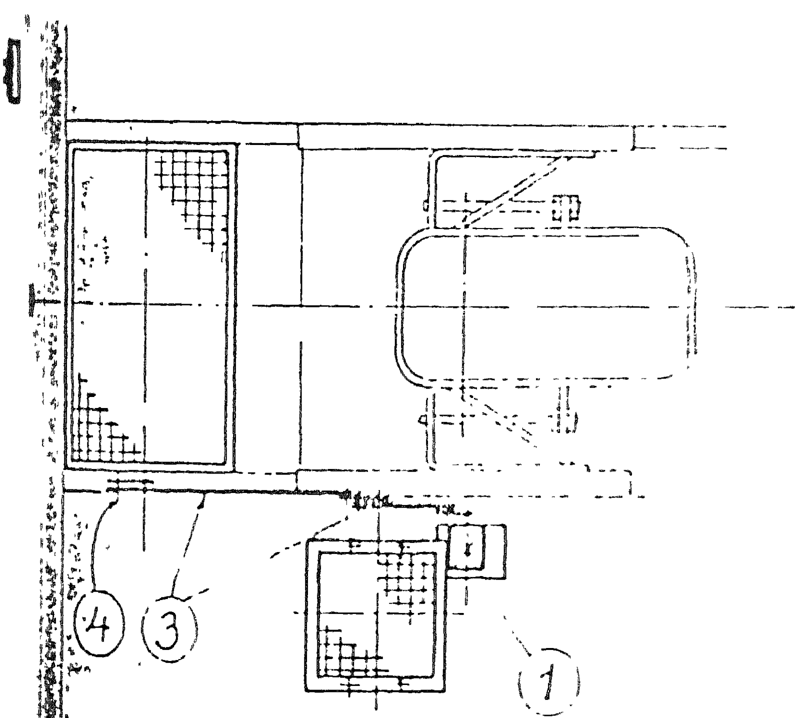
1 BLower 2 Trim Valve 3 Safty Head
4 Mixer 5 Motorised W regulator 6 Salinoid Valve
7 Gas Valve
8 Pressure Guage

ASPIRATION ET DECOMPRESSION D'AIR

Commande automatique



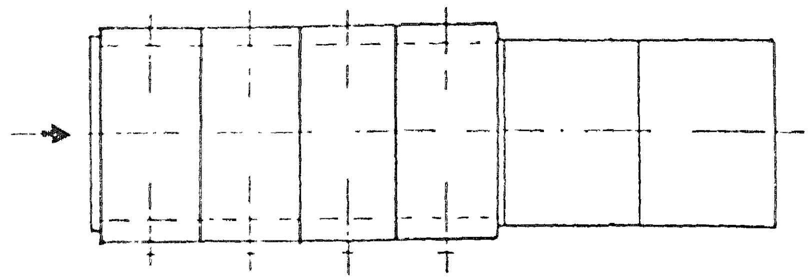


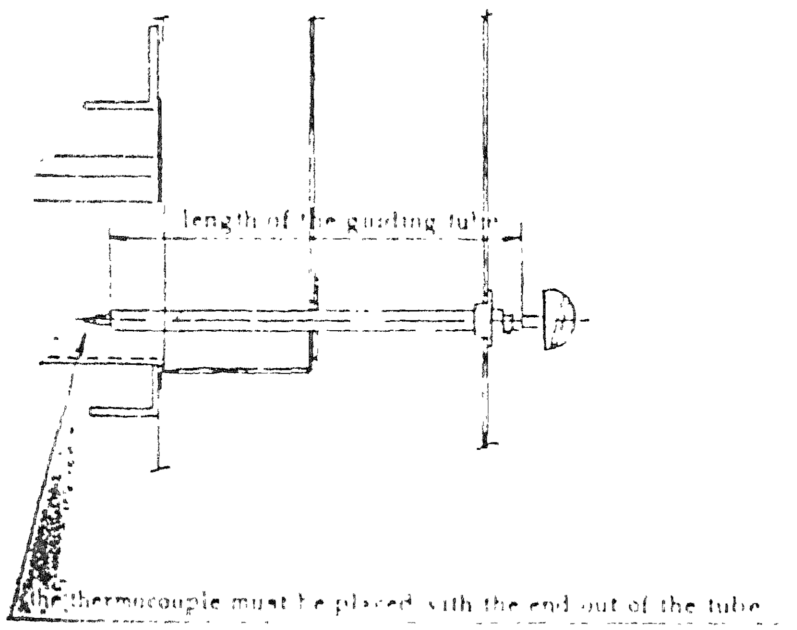


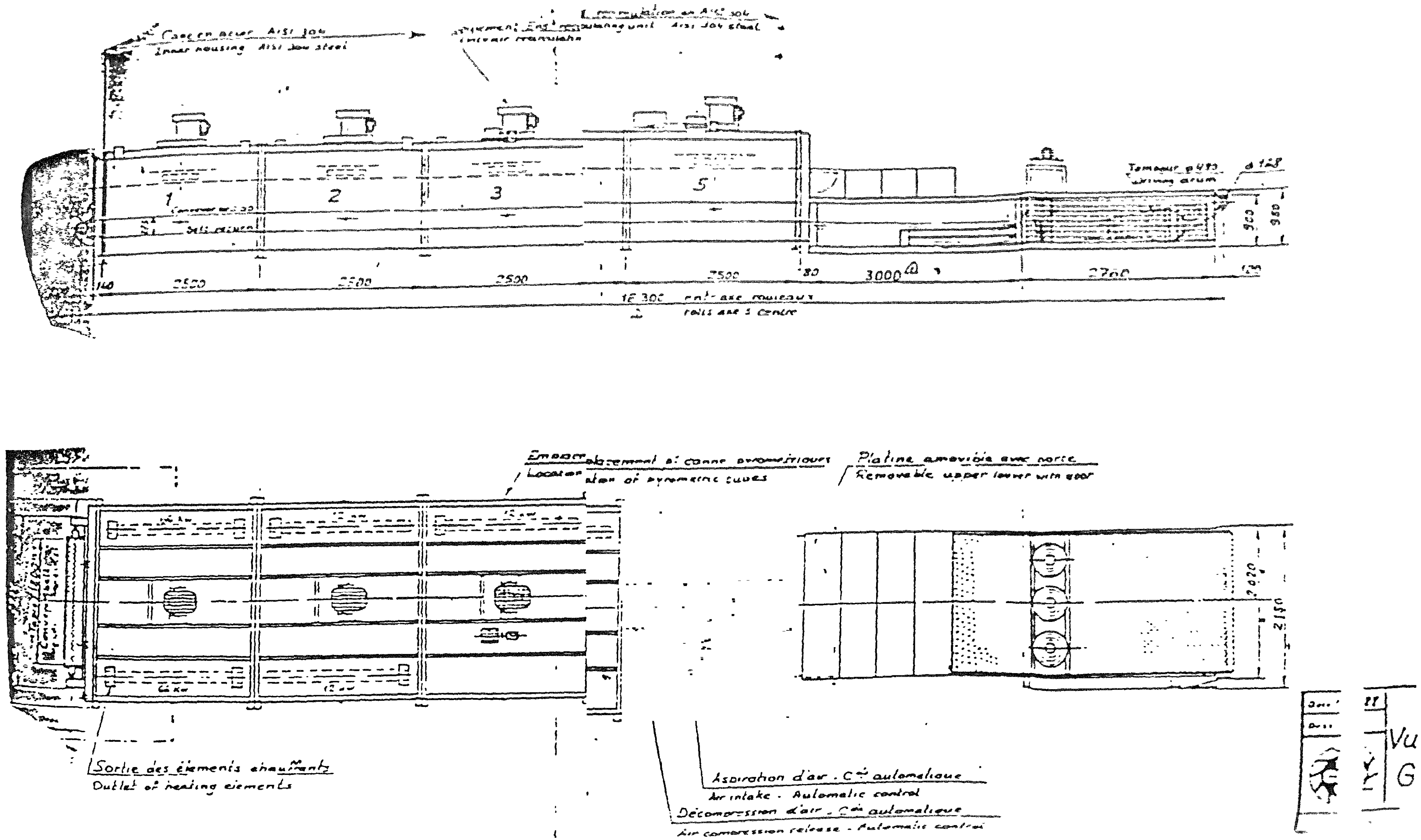
Montage .

- Fixer le servo moteur (1) avec son bras de levier réglable sur son support (2)
- Fixer les rotules (4) sur tous les bras
- Relier les rotules 2 à 2 par les différentes tringles de longueurs appropriées (3) et les fixer par les vis (5)
- Vérifier le fonctionnement et positionnement des vannes et registres après mise sous tension du servo moteur (1)

LOCATIONS AND REQUIRED SPACES
OF THE PYROMETRIC TUBES.







Caisson acier AISI 304
Inner housing AISI 304 steel
Élément de recirculation
Internal air recirculation
Circulation en AISI 304
Recirculating unit AISI 304 steel
1
2
3
5
2500
2500
2500
2500
140
80
3000
2700
16 300 entr-axe rouleaux
rolls axe s centre
Tambour ø 493
Driving drum
ø 128
900
950
Sortie des éléments chauffants
Outlet of heating elements
Emplacement des cannes pyrométriques
Location of pyrometric tubes
Platine amovible avec porte
Removable upper louver with door
Aspiration d'air - C^de automatique
Air intake - Automatic control
Décompression d'air - C^de automatique
Air compression release - Automatic control
2020
2150
Vu
G

Energy Conservation in Compressor and Compressed Air Network

Shashank Jain
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Compressed Air Network

1.0 Introduction

Compressed air is used in almost all types of industries and accounts for a major share of electricity use in some of the plants. It is used for a variety of end-uses such as pneumatic tools & equipments, instrumentation, conveying, etc. Compressed air is preferred for many such applications in industries because of its convenience and safety.

Normally, the compressed air is an overlooked area in most of the industries. Compressed air is a costly source of power, about 7 to 10 times the cost of electricity. It is essential for this reason that the compressed air must be used wisely and economically. Better maintenance practices and elimination of wastage would help in improving the performance of compressed air systems. This write-up focuses on generation and utilisation of compressed air in the plant.

2.0 Types of compressors

Compressors can be broadly classified as dynamic and positive displacement types. Dynamic compressors are centrifugal compressors and are categorised as radial and axial flow types. Positive displacement compressors are categorised as reciprocating and rotary compressors, under which there are further sub-classifications. Dynamic compressors increase the velocity, which is then converted to increased pressure at the outlet. Positive displacement compressors increase the pressure of the gas by reducing the volume. The most commonly used compressors in the industries are reciprocating, centrifugal and rotary type

2.1 Centrifugal compressors

Centrifugal compressors are required where high quantity of compressed air is constantly required. The major limitation of a centrifugal compressor is that it operates at peak efficiency at design point only and any deviation from the this point will be detrimental to its performance. A small change in compression ratio produces a marked change in compressor output and efficiency. Centrifugal machines are less efficient than reciprocating machines at smaller capacities, but are better suited for applications requiring very high capacities. Centrifugal compressors have low initial cost and are compact for large capacity requirements. The advantage with centrifugal compressors is smooth pulsation free operation over a wide variation of flow rate with a relatively small change in pressure. They require less maintenance than the reciprocating compressors. The output of centrifugal compressors can

be controlled by using variable inlet-guide vanes, throttling of suction pressure or throttling of discharge pressure.

2.2 *Reciprocating compressors*

Several types of reciprocating compressors are available viz. single-or multi-stage, lubricating & non-lubricating, and single & double acting. Single stage compressors are, normally, used for up to a pressure ratio of 4 and multistage compressors are economical above this ratio. Other associated advantages with multistage compression are reduced air temperature, pressure differential which reduces the load and stress on valves and piston rings. Non-lubricating compressors are especially used for providing instrument air and for processes which require oil free air. Double acting compressor is used for higher capacities as the quantity of air delivered is double at a given speed. Reciprocating compressors are generally best suited for medium pressure and volume applications. They are comparatively cheap, rugged in design, and have fairly high efficiencies. The disadvantages with this type are the pulsating output and higner installation cost due to relatively high vibrations.

2.3 *Rotary screw compressor*

Screw compressors have several advantages over reciprocating compressors. They are inherently more reliable and require less maintenance as they have few moving parts. Also, the maximum temperature anywhere in the compressor does not exceed 100°C, thus obviating the need for cooling the casing. In screw compressor suction and discharge valves are replaced by ports in the housing and the piston by rotors. It consists of two helical rotors. An electric motor drives a rotor shaft which in turns drive the other rotor. These compressors have less wear and tear, less vibrations and requires smaller foundation.

The advantages with screw compressor are smaller size, lighter weight, step less capacity control and requirement of less starting torque. Also, the performance of screw compressors, unlike reciprocating and centrifugal compressors, are not affected by the presence of moisture in suction air.

2.4 *Rotary sliding vane compressor*

The rotary sliding vane compressor consists of a rotor in a cylinder which is slightly bigger than the rotor. The rotor has a number of radial slots which hold a set of vanes which are free to move in and out within the slots. As the rotor moves, a pair of vanes approaches the air

suction port and the air fills in the space between rotor and cylinder. Compression starts as the pair of vanes crosses the edge of suction port. Now the vanes which have gotten the maximum extension, at air suction port, start sliding back in to the rotor slots because of eccentricity of cylinder wall. The air is get compressed as the space between rotor and cylinder reduces. The compression continues until the vane approaches the discharge port after which the compressed air releases into the system.

These are two types namely; water cooled and oil cooled. The specific power consumption of oil cooled compressor is higher than that of water cooled compressor. The advantages with rotary vane compressor are reliability, low maintenance cost, low discharge air temperature, low starting torque and low foundation cost.

3.0 Compressor selection

Compressor is the heart of the total compressed air network, hence, its selection must be done very care fully. Each type of compressor has its own merits and demerits and, therefore, all these factors must be critically evaluated before making a choice. It is always better to consult the compressor suppliers also. Some of these important factors to be considered for compressor selection, are described below.

3.1 Number of compressors required

It is always better to have a battery of part capacity compressors with a sequence controller, totaling the requirement instead of one full capacity unit. Most of the time, compressed air requirement is less than 100% of the installed capacity. So, this arrangement will provide flexibility and backup during maintenance or break downs.

The disadvantage of this arrangement are that the full load efficiency of smaller compressor is less than that of a large one and also it entails large capital investment

3.2 Cost of operation

This is the single largest factor which determines the type and size of compressor. The full load power requirement or efficiency should not be considered if the compressed air demand is fluctuating. The operating profile of the compressors in the plant is to be ascertained first and based on it the power need of various options available be evaluated

Reciprocating and centrifugal machines draw less power, comparatively, at lower loads. However, it is not applicable for multiple compressor installations where one compressor operates at full load to meet the base requirement of the system and another comes on operation to meet the peak in demand.

Multistage compressors are less power consuming and generates compressed air more efficiently at lower temperature but the cost of the compressor and wear and tear is high for such compressors. Therefore, it has to be justified on the basis of initial and total operating cost. **Figure -1** and **figure -2** give the relative full load power requirement of lubricated and non lubricated compressors respectively.

Figure 1: Specific power consumption at 100 psig (for lubricated compressor)

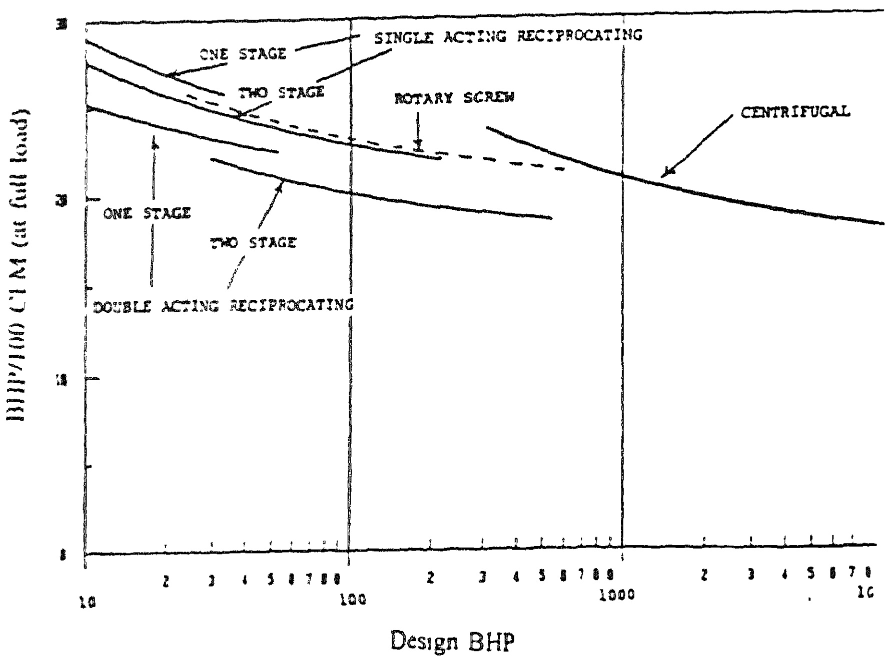
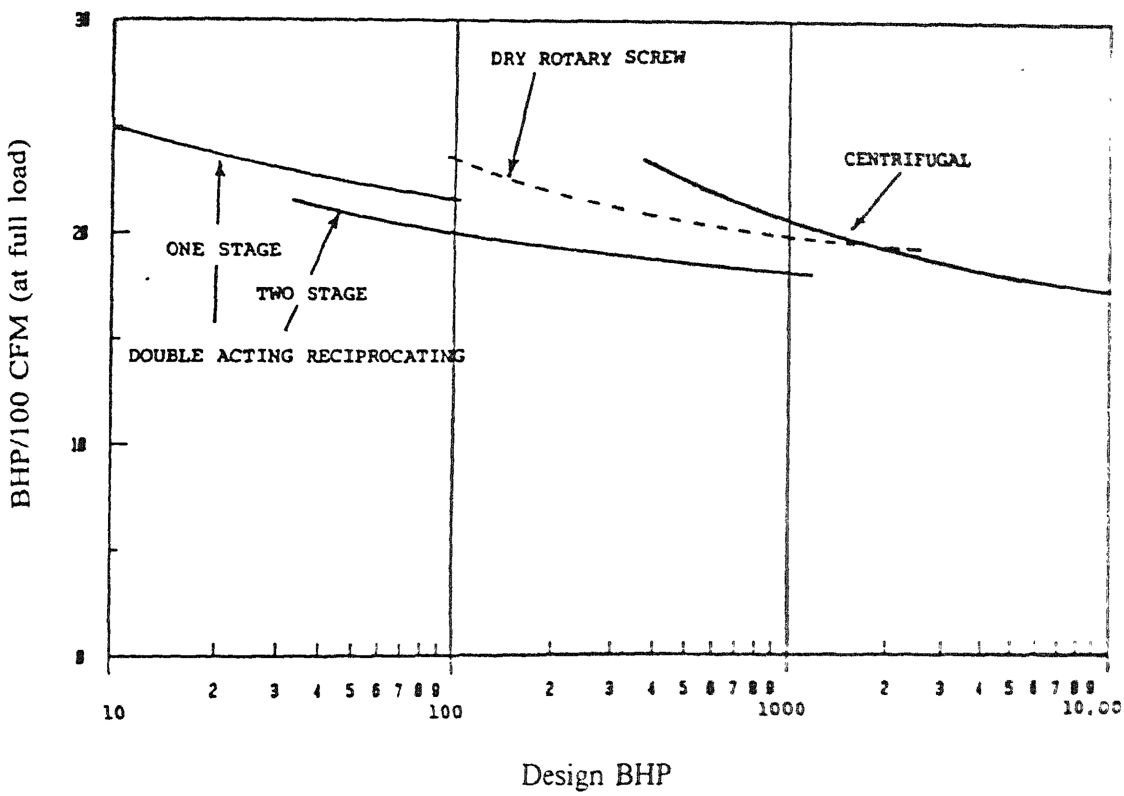


Figure 2: Specific power consumption at 100 psig (for non-lubricated compresors)



3.3 *First and installation cost*

Normally, it is the first cost which decides the type and make of the compressor. However, more important is total cost which includes all the cost incurred on the account of installation and operation of the compressor. Installation cost is lower for centrifugal and rotary compressor as they generate less vibrations whereas it is high for reciprocating compressor which needs a comprehensive foundation. Rotary and centrifugal compressors require less space as they do not need any air storage tank

3.4 *Quality of air*

This factor sometimes determines the type of compressor to be procured. In some specific plant operation, oil free compressed air is needed as impure air may lead to mal-functioning

of the user. Therefore, oil free compressors are required for such purposes. However, lubricated compressors can also be used at these instances, but with high quality oil filter.

4.0 Performance monitoring of compressor system

Followings parameters are need to be monitored regularly for assessing the performance of air compressors and to improve it the same.

4.1 Pump-up or capacity test

This test determines the pumping capacity of the compressors in terms of free air delivery(FAD) i.e air pumped at atmospheric conditions. It requires the isolation of air receiver from the system and only the compressor, whose pumping capacity has to be determined, be connected to it. Drain the receiver. Now, switch on the compressor and observe the time taken by the compressor to maintain the working pressure in air receiver(compressor on time or on load time). Minimum three readings are required to calculate an average value of time Calculate the volume of the pipe line between compressor and receiver The capacity of the compressor can be calculated from the following formula-

$$FAD = \frac{V^{*}(P_2 - P_1)}{P_0{}^{*}T}$$

FAD= actual pumping capacity of the compressor(m^3/min)

V= total volume(m^3) =V'+v

V'= volume of the receiver(m^3)

v= volume of the pipe line connected from air compressor to air receiver(m^3)

P_0= atmospheric pressure(1.013 bar absolute)

P_1= initial pressure of the receiver(bar absolute)

P_2= final pressure of the receiver(bar absolute)

T= average time taken(min) =$(t_1+t_2+t_3)/3$

t_1,t_2,t_3= time taken to fill the receiver at working pressure of the system

Compare this value with the design value of FAD. If the difference is more than 20%, it is high time to look at piston rings, cylinder bores, etc

4.2 *Specific power consumption*

It is always better to evaluate the compressors on the basis of this index. It is the actual shaft power to generate 100 scfm(at 7kg/cm²g or at any common pressure) when the compressor is running at full load. This ratio can be calculated when the actual electrical power input(not the rated power of motor) and free air delivery(FAD) in scfm are known

$$\text{Specific power(kW/100 scfm)} = \frac{\text{Actual power}*100}{\text{FAD(scfm)}}$$

This index must be considered for selection and comparison of compressors. **Table 1** shows a comparison between three broadly used compressors. Reciprocating compressors are the most widely used in the industries. These are energy efficient but require more maintenance to ensure its efficiency. Screw and centrifugal compressors require less maintenance and are used for large requirements of compressed air and where the production down time is very expensive. Centrifugal machines can give even better efficiencies than reciprocating compressors at larger ratings.

Table 1: Comparison of specific power consumption(at 3 kg/cm²g)

Compressor type	*Reciprocating*	*Screw*	*Centrifugal*
Free air delivery(scfm)	5277	5254	5415
Power consumed(KW)	492	600	523
Specific power(KW/100scfm)	9.32	11.42	9.66

4.3 *Quality of air intake*

Air intake to the compressor should be clean, cool and drawn from outside rather than from the compressor room. Intake of hot air reduces the capacity of the compressor and also increases the cooling load. Likewise, dirty air can choke the suction line or may result in to excessive wear of moving parts. The intake air should also be dry. Therefore, air suction should be from the place away from boilers, furnaces, cooling towers, cooling ponds, source of chemical vapors, etc. A coarse air filter should be incorporated at the suction air duct. It must be remembered that every 5°C raise in intake air temperature will increase the power consumption by 2%.

4.4 *Compressor cooling*

The rise in temperature of the gas during the compression limits the pressure level achieved by single stage compression. Hence, multi staging is necessary to get higher pressures. Multi staging with inter stage cooling also help to bring air compression closer to iso thermal compression which consumes less energy(than adiabatic compression). Cooling helps in reducing the temperature and volume of the gas, resulting in reduced power consumption. Hence, multi stage compression is more efficient above the pressure ratio 4. Compressor are normally cooled by air or water except for oil flooded rotary compressors. Air cooling is limited to smaller size compressors whereas the water cooling is recommended for big size continuous running compressors. Water cooling is more effective because of four times heat absorption capacity than the same quantity of air and its temperature is always lower than that of ambient air.

4.5 *Compressor operating pressure*

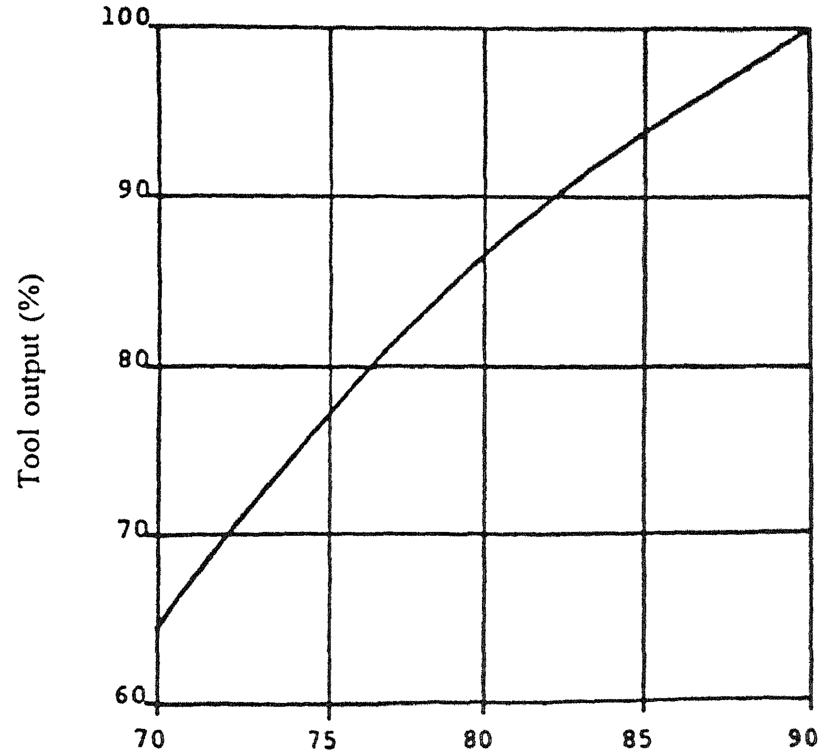
The discharge pressure should be kept at the minimum required for the process or operation of pneumatic equipments for a number of reasons, including minimising the power consumption. Also, compressor capacity varies inversely with discharge pressure and power consumption increases which is evident from the **table 2.** Another disadvantage of higher discharge pressures is the increased loading on compressor piston rods and their subsequent failure. Reducing the higher air pressure(generated for buffer storage) then operating pressure is the waste of energy and cost. Also, at higher pressure air leakages from the same size of orifice increases. An increase in operating pressure by 1kg/cm^2 can increase energy consumption by 4%

Table 2: Power consumption at different pressures

Pressure (kg/cm^2)	FAD (scfm)	Shaft power (KW)	Specific poewr (KW/100 scfm)
3	662	87	13.41
4	618	92.6	14.98
7	652	123	18.87
8	649	128	19.72
10	671	150	22.35

On the other hand, lower air pressure, than required, reduces the productivity of pneumatic tools drastically. Most of the air tools are designed to operate at 90 psig. Performance of these

Figure 3. Effect of air pressure on the efficiency at air tool



tools reduces by 1.4% for every 1 psig drop in pressure. **Figure 3** shows the decrease in performance of air tool with reduction in designed operating air pressure

4.6 Capacity control and power consumption

Compressor systems in the plant normally are designed to deliver variable air volume at fixed pressure. Most air compressure in industry work at part loads and, therefore, employed with some capacity control mechanism to reduce the the compressor out put according to sytem demand. The type of capacity control mechanism used have a significant effect on energy consumption Some of the available methods are briefed below

4.6.1 Two step(start/stop)

This is the simplest capacity control method which turns on off the compressor in response to the low/high system pressure respectively Delivery capacity is limited to two values, 0 and 100% capacity. This control mechanism is limited to small capacity air compressors having small motors. This is the most efficient way of capacity control as idle running is eliminated completely.

4.6.2 Two step (load/unload)

In this case, compressor unloads when the set pressure is achieved. This is analogous to start/stop control but in this type of control compressor, instead of motor, is controlled. When the compressor unloads, the motor continues to operate but at a much reduced load and no compressed air is delivered to the system.

4.6.3 Multi step

Compressor that operates at two or more partially loaded conditions can more closely match the compressor output to the system demand. This type of control mechanism requires multiple pressure switches each operating at pre-defined intervals over the pressure control range. These controls are applied to double acting compressors resulting in a five steps control with delivery capacities of 0, 25, 50, 75 and 100% of the full capacity.

4.6.4 Throttling

By using this control method compressor output can be very easily matched with the system demand. This is done by reducing the inlet to the compressor. In this mechanism, part load operation is less efficient than the full load as reduced capacity is not reflected in a comparable reduction in power consumption. This type is normally used for reciprocating compressors. A modified form of throttling can also be used for all type of compressors in which compressor output is linked with the system pressure and inlet valve operates accordingly. By this control type capacity can be controlled to any level between 0-100%.

4.6.5 Variable speed control

Variable speed can provide capacity controlin 20% to 100% range. While the efficiency of reciprocating compressor increases at lower speed.the same of screw compressor decreases

5.0 Compressed air distribution system

Distribution of compressed air is as important as generation and consists of air pipings after airconditioning equipments(dryer, etc.) to the user ends Normally, the compressors are located at a central place in the plant and the compressed air travels a long distance because user points are located over large areas This results in large pressure drops due to long pipe lines and more numbers of pipe fittings.

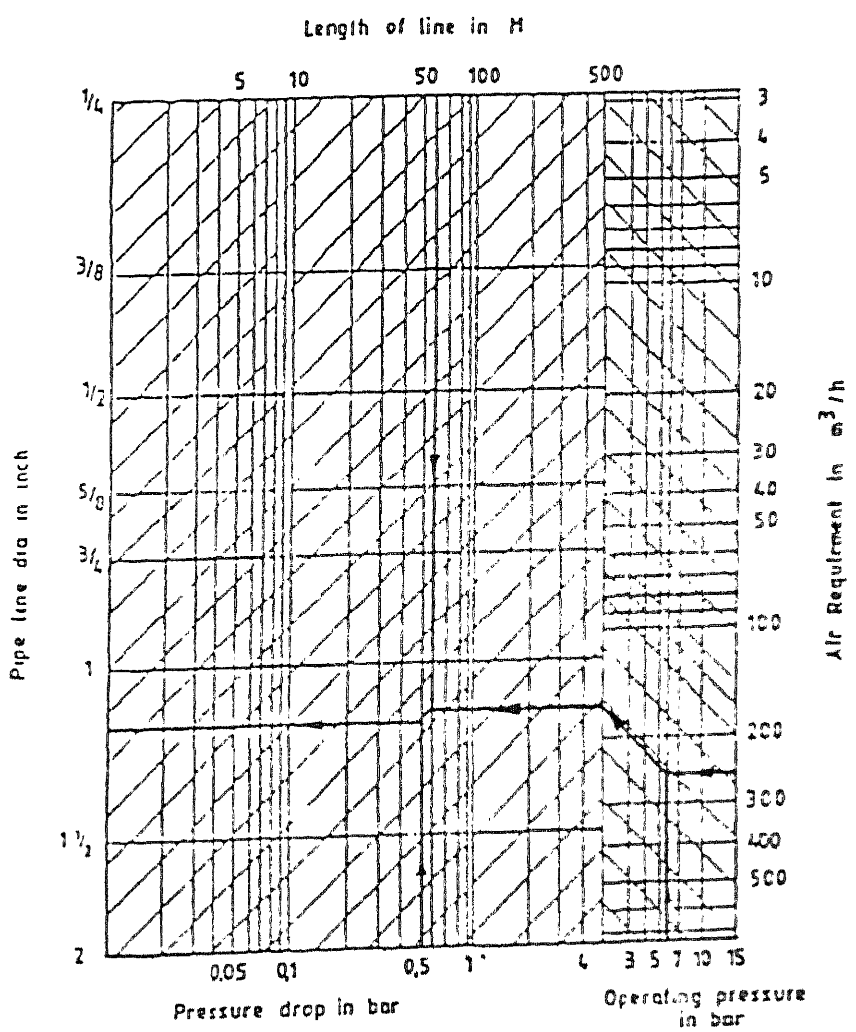
Benefits of generating air efficiently can not be availed until the distribution system is efficient. Efficient system means proper pipe sizing, minimum pressure drops and leakages Though some leakages are inherent in the system but total leakages should not exceed 5%-

10% of the total compressed air generation. Similarly the pressure should not drop more than 7psi till air receiver and and not more than 12 psi in complete compressed air network.

5.1 *Piping layout*

All compressed air piping should be laid out in such a way to minimise pressure drops during trasnsmission. Selection of pipe lines for compressed air supply, depends upon the quantity of air, pressure in the system, length of the pipe line and pressure drop. Too high a velocity, because of smaller pipe sizes, will result in high pressure drops whereas bigger pipe sizes will reduce the pressure drop for the same compressed air flow but increase the capital investment Air velocity in the pipe should be kept in a range of 6-10 m/s. Appropriate pipe sizes can be selected at various system pressures, pressure drops and flow rates from the nomogram given in **figure 4**.

Figure 4. Nomogram for determining pipe diameter



For an example, determination of pipe diameter for carrying 250 m^3/hr of air at 6 kg/cm^2 at a distance of 60 metres with a pressure drop of 0.5 kg/cm^2 from the **figure 4** is shown with dark lines.

Following points must be considered while designing the distribution network-

- The main line should have a minimum slope of 1" in every 10 ft in the down stream to facilitate the water drainage from the nearest drain point. However, this slope is not needed if effective air dryer is provided in the system.
- The distance between two drain points should not exceed 30 metres.
- Branch tappings should be taken from the top of main pipe line.
- Adequate auto drain traps and strainers must be provided in the main and branch line.
- Seperators should be provided before the pneumatic equipments to get rid of any moisture, still left in the system. Seperators are, however, not required if an effective air dryer is used.
- Valves may be used to isolate lines in the plants where air is not required during certain shifts or days.

5.2 *Air receiver*

Air receivers perform several functions in a compressed air system. A receiver dampens the pulsation from reciprocating compressor and makes the flow of air smooth, acts as a reservoir to meet short time excess demand of the system, etc. The compressed air velocity reduces when it enters in the receiver and, hence, it becomes cooler. Because of cooling, some of the associated water condenses and accumulate at the bottom of receiver from where it is removed by a valve or trap, thus reducing the load on dryers. The oil mist is also gets seperated in the receiver and drained out with water.

The size of the receiver, according to IS specification, should be at least 6 to 10 seconds capacity(in FAD) of compressor. It is always beneficial to over design the air receiver. The receiver should be fitted with a pressure gauge, safety valve and a moisture drain valve.

5.3 *Leakage test*

The leakage in the compressed air system can be quantified by running the compressor with all the air using equipments shut off. Note down the time when system attains desired pressure or compressor unloads. This pressure will fall because of leakages in the system and the compressor will come on the load again. Note this time. The period for which the

compressor is on load or off load should be recorded at least three times to calculate an average value. The leakages can be estimated as

$$L = \frac{FAD^{*}\, t_1}{t_1+t_2}$$

Power wasted in Rs./year = 5.54 * L * Operating hours per annum * Rs/KWH

L = leakages (m^3/min)
FAD=actual free air delivery of the compressor (m^3/min)
t_1 = average on load time of compressor(sec)
t_2 = average off load time of compressor(sec)

A certain amount of wastage through leakage in any compressed system is inevitable but air leakages above 5%, certainly, needs indepth study of the system. By regularly carrying out the leakage test in the plant and plugging the leakages will result in saving of handsome amount.

5.4 *Detecting leakage points*

It is difficult to detect air leakage as they can not be seen and smelt. While large leakages are easily detected by hissing sound or by ultrasonics generated, it is difficult to detect small leakages which can only be detected by applying soap solution on pipe lines, joints, etc. It is recommended to get the entire distribution system tested with soap solution once in six month.

The air lost due to leakages can be quite significant depending on the air pressure. **Table 3** gives the leakages through various orifice size and energy wastage at 7kg/cm^2 air pressure.

Table 3. Power wastage at 7kg/cm2

Orifice dia	*Air leakage (scfm)*	[illegible]
1/64"	0.406	0.08
1/32"	1.62	0.31
1/16"	6.49	1.26
1/8"	26	5.04
1/4"	104	20.19

6.0 Moisture separation

Air contains varying quantity of moisture depending upon the temperature and the relative humidity of the air. At 27°C and atmospheric pressure 100m^3 of saturated air will contain 2.55 kgs of water. If this 100m^3 air is compressed to 7kg/cm^2, it can not associate more than 0.32 kgs of water as vapors at 27°C and balance 2.23 kgs of water is left behind in the pipe lines or receiver.

This moisture when remained in the system may lead to several problems such as corossion, wear & tear of equipments, machines/tools and pipes due to water hammering, degrading and removal of lubricants(for lubricating type of compressor) , increased maintenance cost and down time, etc. The tendency of air to retain water increases with the temperature and due to compression, temperature of air increases. Hence, compressed air, immediately after compressor has more tendency to carry water with itself. This compressed air gets cooled during its destribution in the network leaving behind an appreciable quantity of water in the system. Therefore, it is necessary to remove the moisture before the air enters into the distribution system and cause demage. There are various ways to remove moisture from the compressed air which are discussed below in detail.

6.1 After cooler

Aftercooler is the most commonly used device which not only removes the moisture but also reduces the compressed air temperature. Aftercooler is a heat exchanger which uses water or air to cool down the compressed air. As the dry bulb temperature of air reduces, its dew point also comes down and in no case it exceeds the dry bulb temperature at same pressure . Dew point is the temperature at which the air becomes fully saturated with water vapours and at any temperature below this water vapours condenses.

Aftercoolers are of two types namely(i) air cooled, used for small machines;(ii) water cooled, used for large machines. A properly designed aftercooler can effectively remove upto 60-70% of total moisture of compressed air and bring down the air temperature to a level of 5-15°C above the ambient.

A seperator or trap must accompany the aftercooler to remove the water from the system as soon it forms to avoid the carry-over. An oversized aftercooler is always beneficial as it reduces both pressure drop and temperature.

6.2 *Dryers*

For further reduction of the moisture, dryers are used. Three types of dryers are broadly used in industries. To prevent the water vapors to condense in the destribution system, the pressure dew point of the air after the dryer should be around 10°C lower than the lowest expected air temperature in the system.

The oldest type is deliquescent type which entails low first cost and does not require energy except the little pressure drop in the system. The only cost involved is the replacement of deliquescent material. A deliquescent material e.g. salt, potassium carbonate, etc. is used to absorb the moisture from the air. This type of dryers are capable of reducing dew point by 8-20°C. These dryers are of no use where ambient temperature is low. Filter after the dryer is required to avoid any carry-over of the material.

Refrigerent type dryers can bring down the dew point to as low as 2-10°C. Compressed air is cooled in a refrigerent cycle. Operating cost of such dryers is moderate. These dryers are suitable for large capacity plant. A water separator is required after the system

Third type of dryers, desicant dryers, are capable of reducing the dew point to -40 °C. These are costliest and most energy inefficient dryers. Water is adsorbed by an adsorbing material which is regenerated by heating or air purging or both Regeneration under vacuum reduces the energy consumption. Filters, before and after the dryer, are needed to prevent contamination of air and adsorbing material.

7.0 Terminology and conversion

FAD = free air delivery at atmospheric pressure, temperature(35°C) and humidity(70%)

NM³/hr = volume of air at 1.033 kg/cm², 0°C and 0% RH

scfm = standard cubic foot per minute at 14.7 psia, 60°F and 0% RH

M³/hr = NM³/hr * 1.17

scfm = M³/hr * [illegible] 1.53

M³/min = cfm* 35.3

8.0 Case studies

8.1 *Compressed air leakage*

Compressed air leakage test was carried out in an engineering industry to quantify the leakage It was found out that 50% of the compressed air was wasted through leakages

Compressor capacity	= 1065 cfm
Average off load running time	= 0.5 minutes
Average on load running time	= 0.5 minutes
Air leakage	$= \frac{1065*0.5}{0.5+0.5} = 532.5$ cfm
Compressor operating hrs./year	= 4800
Cost of electricity	= Rs. 2.5/KWH
Loss of money per year	= 0.157*532.5*4800*2.5 = **Rs. 10.03 lacs**

It is recommended to identify the leakage points by listening the hissing sound, by using ultrasonic leak detector or by using soap solution. The potential of saving is around Rs. 9.03 lacs per annum allowing 10% (maximum) leakage in the system.

8.2 Pressure reduction

In an industry, all compressors were operating at 100 psig where as the equipment's requirement was 75-80 psig. Pressure drop in the distribution lines were practically nil as the lines were adequately sized.

Capacity of compressor	= 530 cfm
Numbers of compressor working	= 3
Operating hours per annum	= 3000
Cost of electricity	= Rs. 1.6/KWH
Power saving by reducing pressure from 100 psig to 85 psig	= 4%
Energy savings	= 30000 KWH/annum
Monetary savings per annum	= Rs 48000/-

It is recommended to reset the pressure switch to modulate between 80-90 psig. The savings due to this is Rs 48000 per annum without any investment.

Environment Norms and Pollution Abatment Measures in Glass industry

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PAPER
ON
POLLUTION ABATEMENT MEASURES AND ENVIRONMENTAL NORMS
IN
GLASS INDUSTRY

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1.0 Glass industry in India :

The glass industry is one of the oldest industry in the world Glass is being made since last 3500 odd years In India, the first organised glass industry was set up only about 100 years ago Presently, there are over 120 organised units engaged in glass manufacturing in the country, besides tiny scale units making traditional bangles and mouth blown articles etc which are located mostly at Ferozabad town Over the years, though the glass production has increased manifold, the number of glass factories is reducing as a large number of small and tiny units are closing down due to uneconomic scale of operation, giving way to larger economically viable units Glass industries are fairly uniformly distributed throughout the country except for a thick cluster of small industries in Ferozabad The western region has about 39 glass making units, followed by 22 in north region, 18 in east and 14 in south region

2.0 Pollution Aspects in Glass Manufacturing :

The pollution aspects have been described separately for air, water and solid waste pollution

2.1 Air Pollution :

The glass industry primarily gives rise to air emissions mainly from the Glass Melting Furnaces The principal pollutant is Particulate matter from combustion of fossil fuels In addition, depending upon the raw material mix and the type of glass produced, specific pollutants like lead, fluoride may be emitted from a few units The post combustion products with entrainment of process chemicals in some units find their way into atmosphere Particulate matter expelled from the furnace is the result of complex physical and chemical reactions that occur during the melting process During the melting process, carbon dioxide gas bubbles through and propels finer raw material particles from the melt bath Particulate, swept from the furnaces, are partly collected in the brick checker work of the heat exchanger and gas passages and partly exhausted to the atmosphere via chimney

There are a variety of melting furnaces used in glass manufacturing, starting from small Pakai bhattis to Pot furnaces, tank furnaces, open top type furnaces, regenerative furnaces etc Different furnaces gives rise to different type of emissions, like products of combustion, dust particles, hazardous gases like SO_2, Nox, Fluorides, chlorides etc

Mainly, the emissions occur due to incomplete combustion of the fuels The emission from a pot type furnace is initially quite high at the time of fresh batch charging and also (for few hours) before the start of withdrawal of glass, which is due to increased fuel firing rate to achieve and maintain the high melting temperature of the molten bath During the remaining period, the emissions are considerably lower In open top type bangle making furnaces, in the absence of any stack, the emissions disperse in the shop and are fugitive in nature Nevertheless, due to slow and low firing rates, the emissions are generally low In Pakai bhattis, the emission are low because the furnaces being very small and melting temperature require being low, the fuel firing is also slow In regenerative type furnaces, during normal operation the emissions are low, but during reversal of regenerators the emissions are high for a few minutes

The dust emission in the manufacturing of special glasses like lead glass and borosilicate glass is substantially high with the concentration of lead (heavy metal) in the dust being a critical factor

The various polluting gases that are emitted from the glass melting furnaces are SO_2 and Nox The SO_2 originates from the sulphur in the fuel as well as any sulfates in the raw material Due to the reducing atmosphere in the melting furnaces, sometimes elemental sulphur is formed which gets coated in the flue ducts and stack or is discharged through stack in the form of flakes The Nox formation is due to high temperatures in the furnace and excess air and due to presence of potassium nitrate in the raw materials In some units, the fluoride emissions occur where fluoride containing compounds like sodium silicon fluoride or flurospar are used in the raw materials as chemicals Sometimes, chloride emissions can also occur when chloride compounds like sodium chloride are used as refining chemicals

2.2 Water Pollution :

Effluents are generated in some units, mainly from the cullet (broken glass pieces) washing operation and partly from the cooling of moulds, compressor, washing of finished products etc Generally, the effluent quantities are quite low

2.3 Solid Waste Pollution :

Generally there are two sources of solid wastes in a glass industry, the coarse reject sand from the sand screens and waste glass from the furnace

3.0 Environmental norms for Glass Industry :

The Emission Standards for Glass industry as prescribed by the Central Pollution Control Board are as given below

A. Sodalime & Borosilicate and Other special Glass (other than lead)

(a) Furnace Capacity

(i) Upto a product draw capacity of 60 MT/Day	Particulate matter	2.0 kg/hr
(ii) Product draw capacity more than 60 MT/Day	-do-	0.8 kg/Mt of product drawn
(iii) For all capacities	Stack height	$H=14(Q)^{0.3}$ where Q is the emission rate of SO_2 in Kg/hr & H is Stack height in meters
	Total Fluorides	5.0 mg/NM^3
	NO_x	Use of low NO_x burners in new plant

(b) Implementation of the following measures for fugitive emission control from other sections -

(i) Raw materials should be transported in leak proof containers

(ii) Cullet preparation should be dustfree using water spraying

(iii) Batch preparation section should be covered

B. Lead Glass

(a) furnaces -

All capacities	Particulate matter	50 mg/NM^3
	Lead	20 mg/NM^3

(b) Implementation of the following measures for fugitive emission control from other sections -

(i) Batch mixing, proportioning section and transfer points should be covered and it should be connected to control equipments to meet the following standards

Particulate matter	50 mg/NM^3
Lead	20 mg/NM^3

(ii) Minimum Stack height should be 30 meters in lead glass units

(c) Pot furnace at Firozabad Furnace	Particulate matter	1200 mg/NM^3

Note - Depending upon local environmental conditions, State/Central Pollution Control Board can prescribe more stringent standards than those prescribed above

Glass Industries (for all categories)	EFFLUENTS	
	pH	6 5-8 5
	Total Suspended Solids	100 mg/l
	Oil & Grease	10 mg/l

(Ref Pollution control Acts, rules notifications issued threunder, CPCB publication, pollution control series PCL/2/1992 (Volume I), September 1997 edition)

4.0 Pollution Abatement measures :

4.1 Prevention of fugitive emissions :

The fugitive emissions during transportation loading and unloading of the raw materials could be substantially reduced in several ways, such as, using leak proof bags, by lowering the drop heights, installation of enclosures or wind breaking walls, usage of conveyor belts or bucket elevators etc

The fugitive emissions during crushing and grinding operations (such as cullet preparation) could be reduced substantially by implementing modifications like, better control over crushing to required size only and by minimising under-size crushing and also by enclosing the crushing area from all sides and using a spray of water wherever possible at places like primary jaw crusher, roller crushers etc The fugitive emissions while transporting the raw mix from the mixer to the furnace could be substantially reduced by using mono rail type system

In lead glass manufacturing, lead being hazardous substance, it is required to conduct the raw material proportioning and mixing operations under dust extractive hoods and the dust laden air needs to be treated in high efficiency dust control systems like bag filters The workers in the batch preparation area should be provided with dust protection nose covers

In the raw material feeding/charging (to furnace) section, a pusher type batch feeding mechanism in 'Dog house' can achieve lower dust entrainment

Reduction of hazardous gas emissions depends on selection of appropriate fuel as well as burner and furnace design and its operation

4.2 Control of raw materials :

Although glassmakers have traditionally sought fine particle materials for easier melting, these materials have intensified dust carry over in regenerative furnaces A compromise must be reached to reduce this dust carryover Crystals of soda ash, limestone, and other materials may be friable and crush in the mixer, producing excessive amount of fines, screen analysis of individual raw materials should not be combined for estimating the screen analysis of the batch charge. Crystalline shape and density of raw materials should be throughly investigated before raw material suppliers are selected .

Since particulate emissions from soda lime regenerative furnaces increases with an increase in equivalent sulfate (SO3) present in the batch charge, sulfate content should be reduced to an absolute minimum consistent with good glaass making Preferably it should be below 0 3 weight % Equivalent sulfate content of the batch includes all sulfur compounds and elemental sulfur. Compounds of fluorine, boron, lead, and arsenic are also known to promote dust carryover, but the magnitude of their effect upon emissions is still unknown In sodalime glass manufacture, these materials should be eliminated or should be present in only trace amounts From the standpoint of supressing the stack emissions, cullet content of the batch charge should be kept as high as possible

4.3 Batch Preparation :

There are a number of ways to condition a batch charge and reduce dust carry over Some soda lime glass manufacturers add moisture to the dry batch, but the relative merits of this process are debatable Moisture is sprayed into the dry batch charge at the mixer as a solution containing 1 litre of surface active wetting agent to about 750 lit of water Surface tension of the water is reduced by the wetting agent so that the water wets the finest particles and is evenly distributed throughout the batch If the moisture content exceeds 3 %, batch ingredients adhere to material handling equipment and may cake in storage bins or batch cans

4.4 Checker Modifications :

The design concept of modern regenerative furnaces, with its emphasis on maximum use of fuel , is also directly committed to reducing dust carry over All things being equal, less fuel burned per ton of glass means less dust entrainment by hot combustion gases and flames flowing across the surface the melting glass Enlarged checkers with increased volume not only reduce fuel consumption and particulate formation but also present a more effective trap for dust particles that are expellled from the melter

4.5 Emission Control measures :

In case the pollution prevention measures do not bring down the emissions below the limits prescribed, only then there is a need to install an appropriate pollution control equipment There are various types of Pollution control technologies for the control of particulate matter Most prevalent systems are discussed below

(i) Baghouse dust collectors

Generally, the temperature of flue gases from glass melting furnaces is as high as 500 to900 deg C If baghouse is to be used as control device, the gases need to be cooled to allowable temperature to prevent burning of the bag cloth Maximum temperatures allowed vary from about 80 deg C for cotton bags, 130 deg C for Polyester bags and upto 250 deg C for Glass fibre bags Cooling of gas could be done with a combination of gas cooling methods like radiation or convection cooling, or using evaporative water coolers or by dilution with ambient air The filtering velocities should be kept in the desired range as prescribed by the filter manufacturer Gas temperature in the bag house should not fall below due point otherwise condensation within the baghouse may cause the particles on the bag surface to agglomerate and choke the cloth pores and corrode the baghouse enclosure

Since the investments in the bag filter house type equipment are on a higher side and controlled cooling of gases to desired temperature is difficult and needs precision and expensive instrumentation, the same would not be suitable for small glass industries

(ii) Cyclones

Cyclones collect particles above 10 microns efficiently, but for particles less than 10 micron size the collection efficiencies are low Since, in case of glass melting furnaces, substantial percentage of particles are estimated to be below 10 microns size which would escape cyclones, the outlet dust concentration would not meet the standard prescribed and therefore not suitable for glass melting furnaces

(iii) Multiclones

Multiclones (a group of small axial entry cyclones enclosed in a casing) can collect particles upto 5 microns efficiently, the balance fines would escape to atmosphere It needs to be tried in a few units, if found satisfactory and meets the standards prescribed, the same could be installed in other furnaces

(iv) Wet Scrubbers

Wet scrubbers of the types like Venturi scrubbers or Impingement Entrainment type scrubbers could collect particles upto 2 microns efficiently It can collect the dust with an efficiency of 85 to 90 % and therefore may meet the emission standard prescribed for glass industries

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